PHYSICS AND STATUS OF TOTEM

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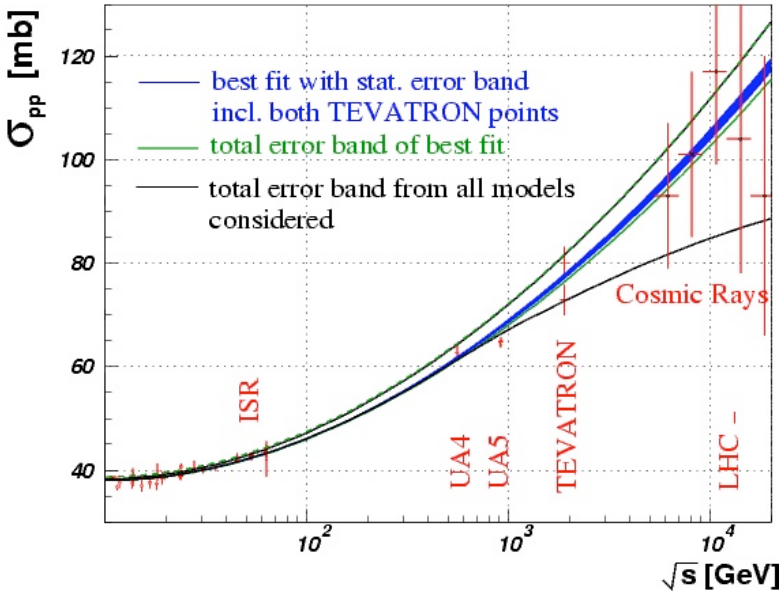
on behalf of the

TOTEM Collaboration

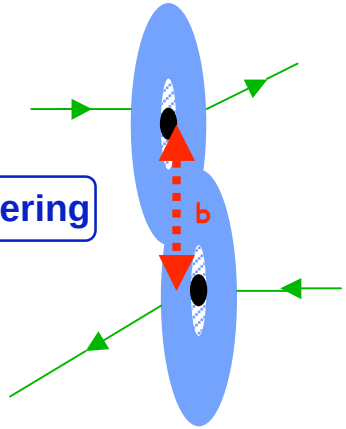
http://totem.web.cern.ch/Totem/

TOTEM Physics Overview

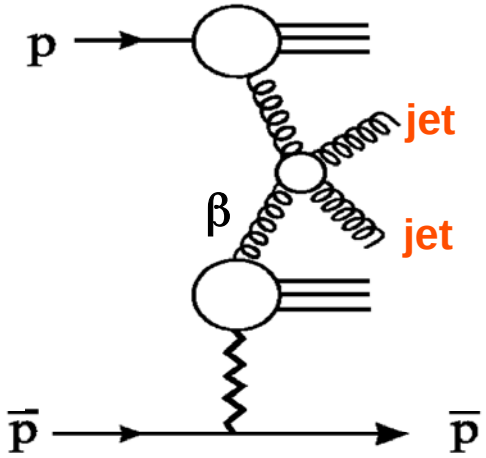
Total cross-section



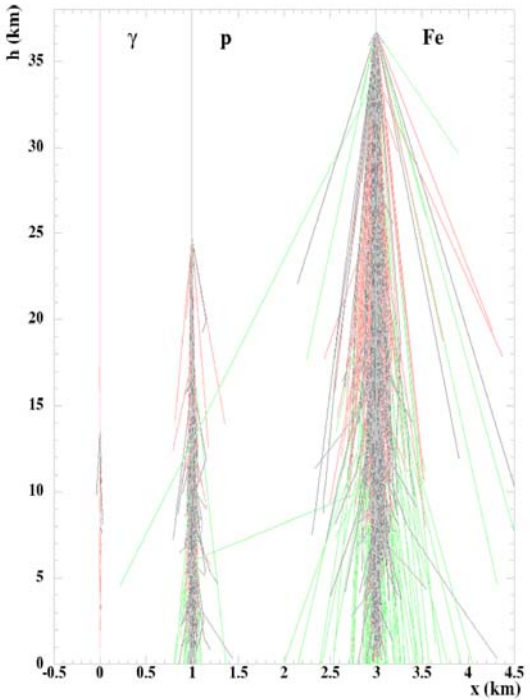
Elastic Scattering



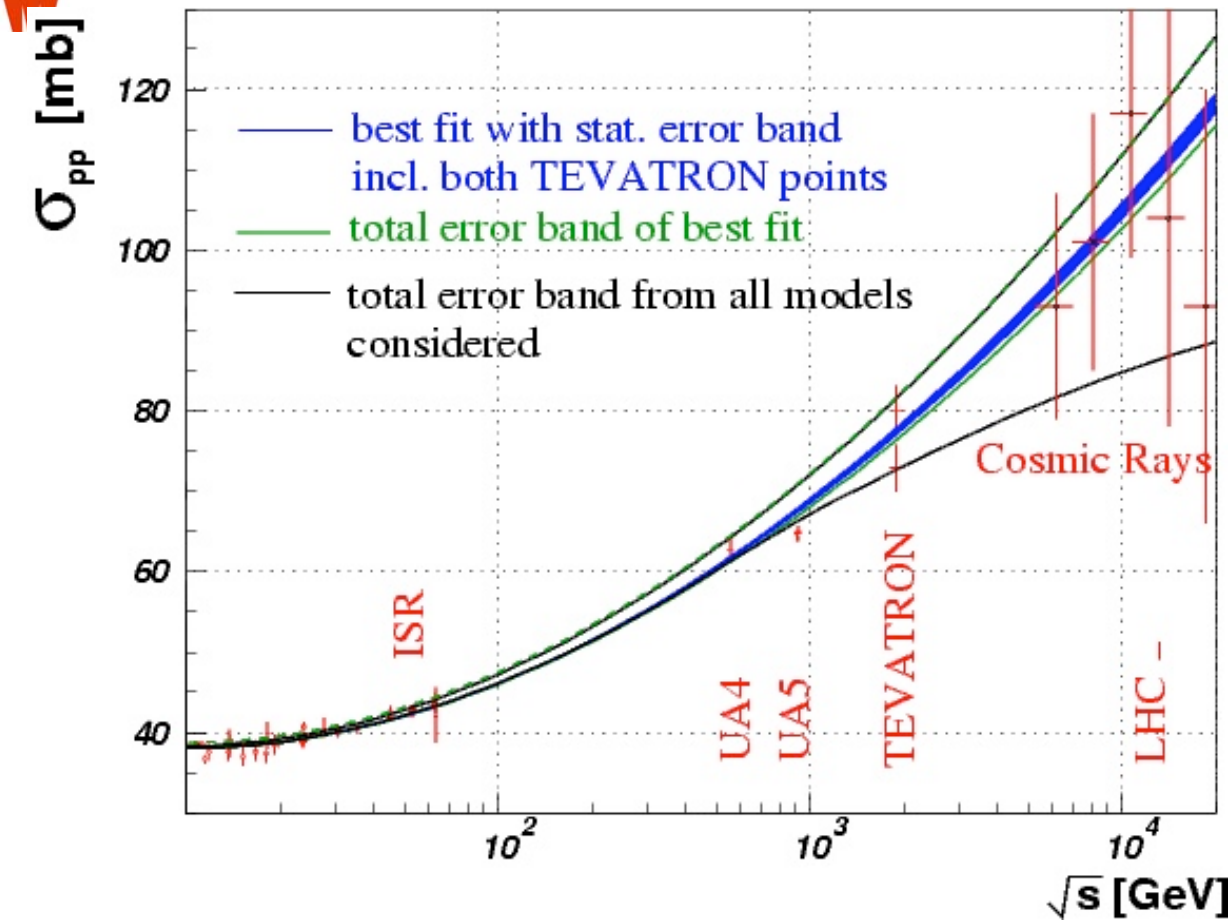
Diffraction: soft and hard



Forward physics



Total p-p Cross-Section



~ $\ln^2 s$

Current models predictions:
90-130 mb

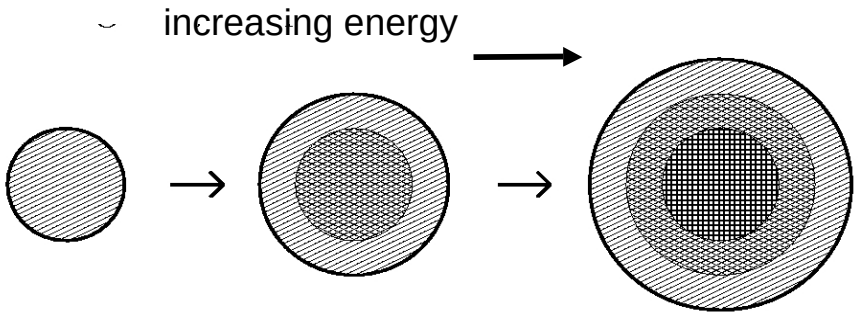
Aim of TOTEM:
~1% accuracy

COMPETE Collaboration fits all available hadronic data and predicts:

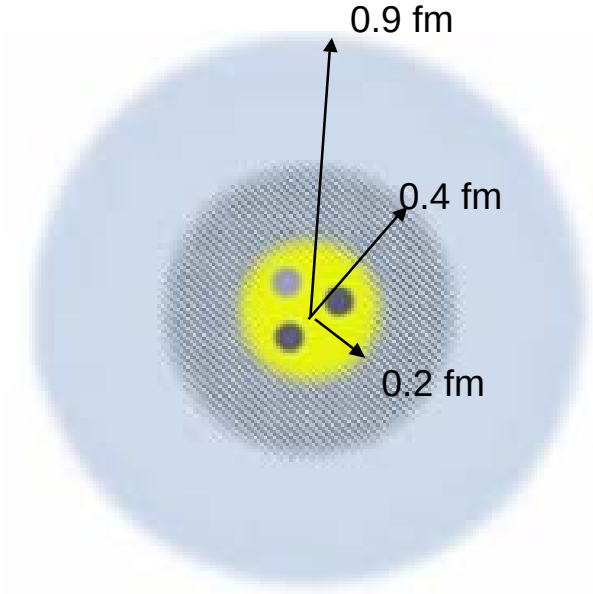
LHC: $\sigma_{tot} = 111.5 \pm 1.2 \,^{+4.1}_{-2.1}$ mb

[PRL 89 201801 (2002)]

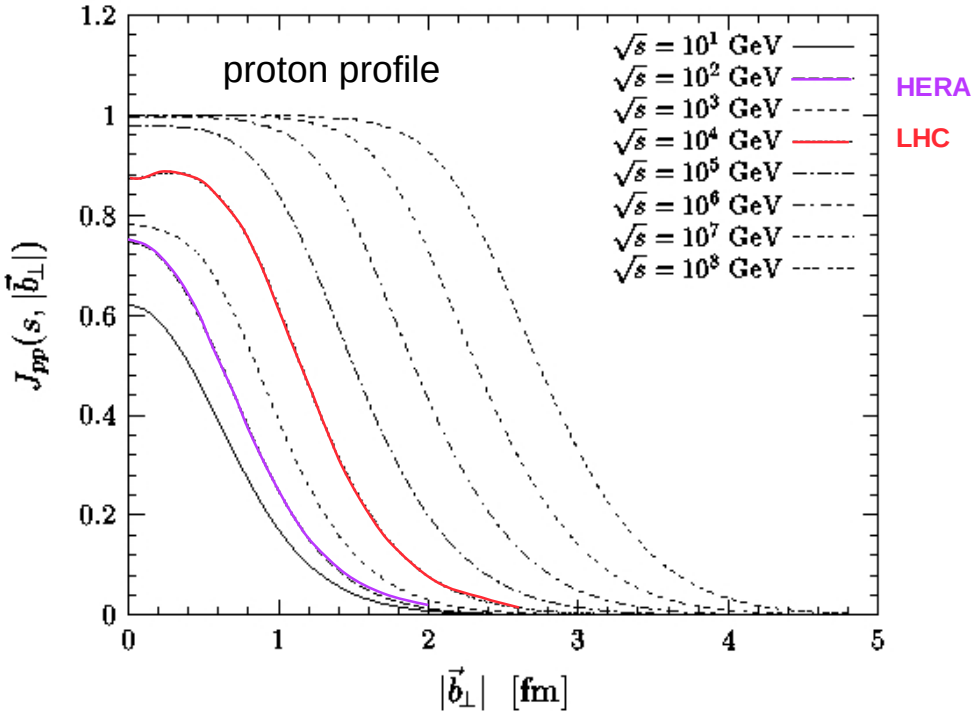
Facts about the proton



blacker
radius increases
edge area increases



proton at LHC



Regge:

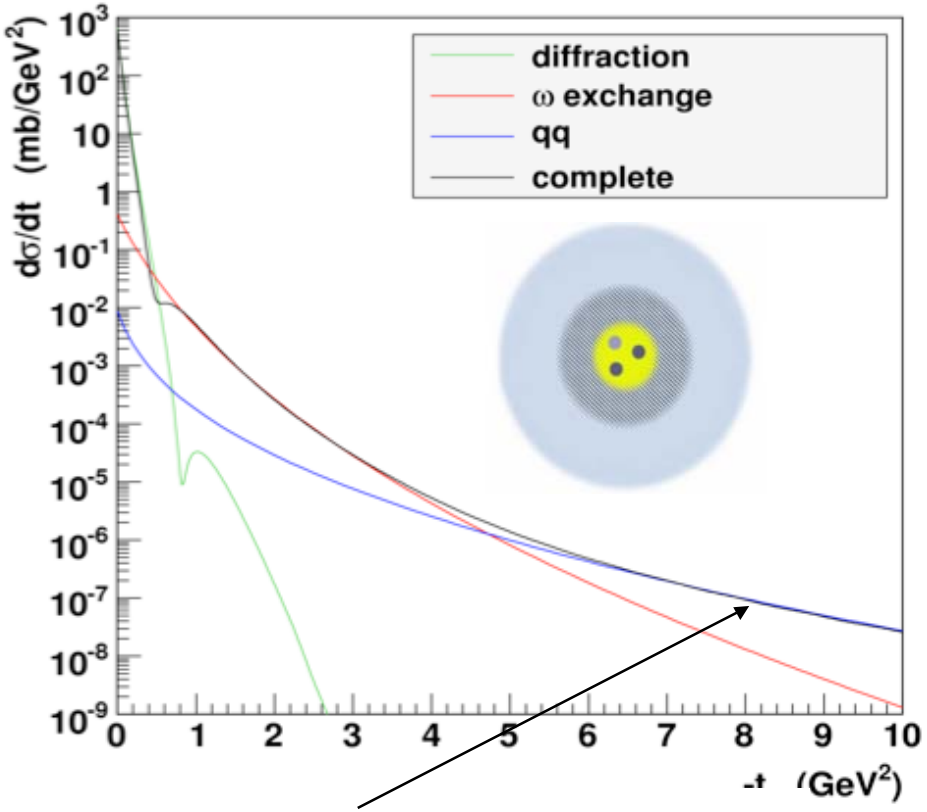
$\sigma_{tot} \sim \sum A_i \, s^{\alpha_i(0)-1}$ $\quad \alpha_P=1.08 \quad \alpha_R=0.54$

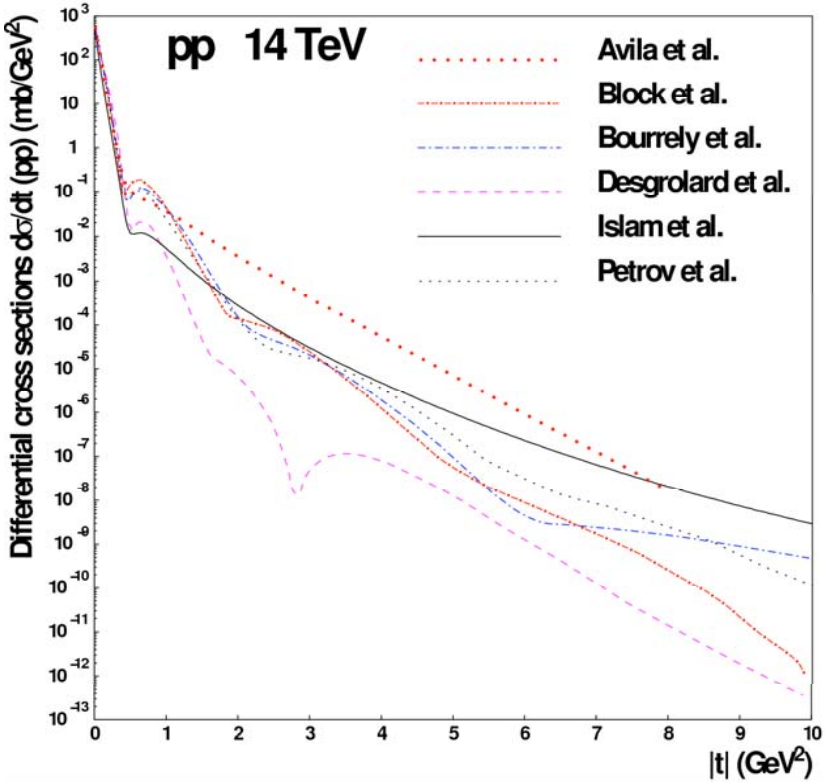
$\sim 21.7 \; s^{0.0808} + 56.08 \; s^{-0.4525}$

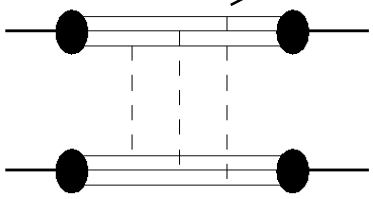
Geom. Scaling:

$\sigma_{el} \sim \sigma_{tot} \sim B(s,0) \sim R^2(s) \sim \ln^2 s$

Elastic pp Scattering: Predictions for 14 TeV







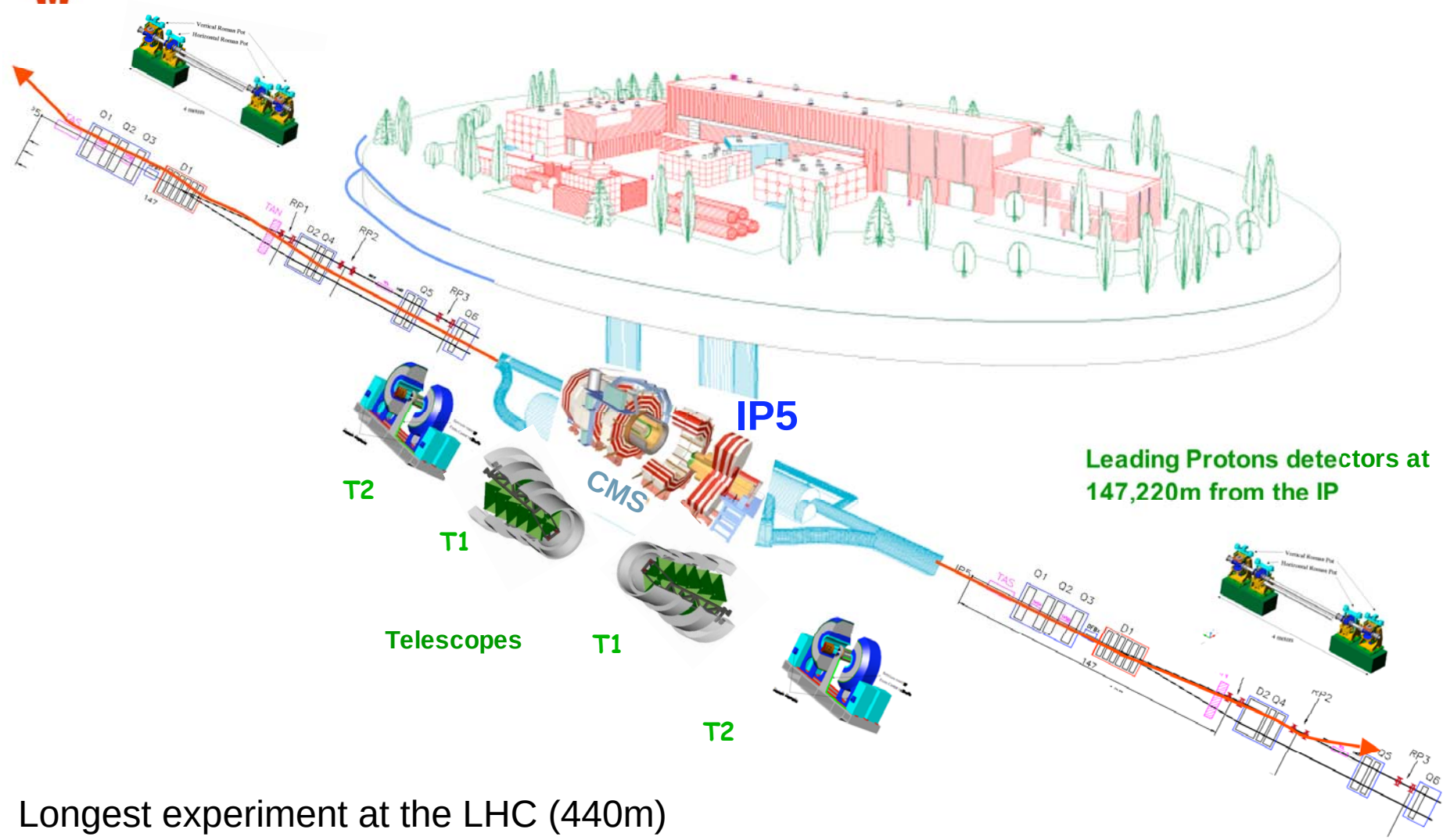
3-gluon exchange at large t:

$$\frac{d\sigma}{dt} \sim Ct^{-8} \qquad \text{independent of } s$$

Big uncertainties at large t

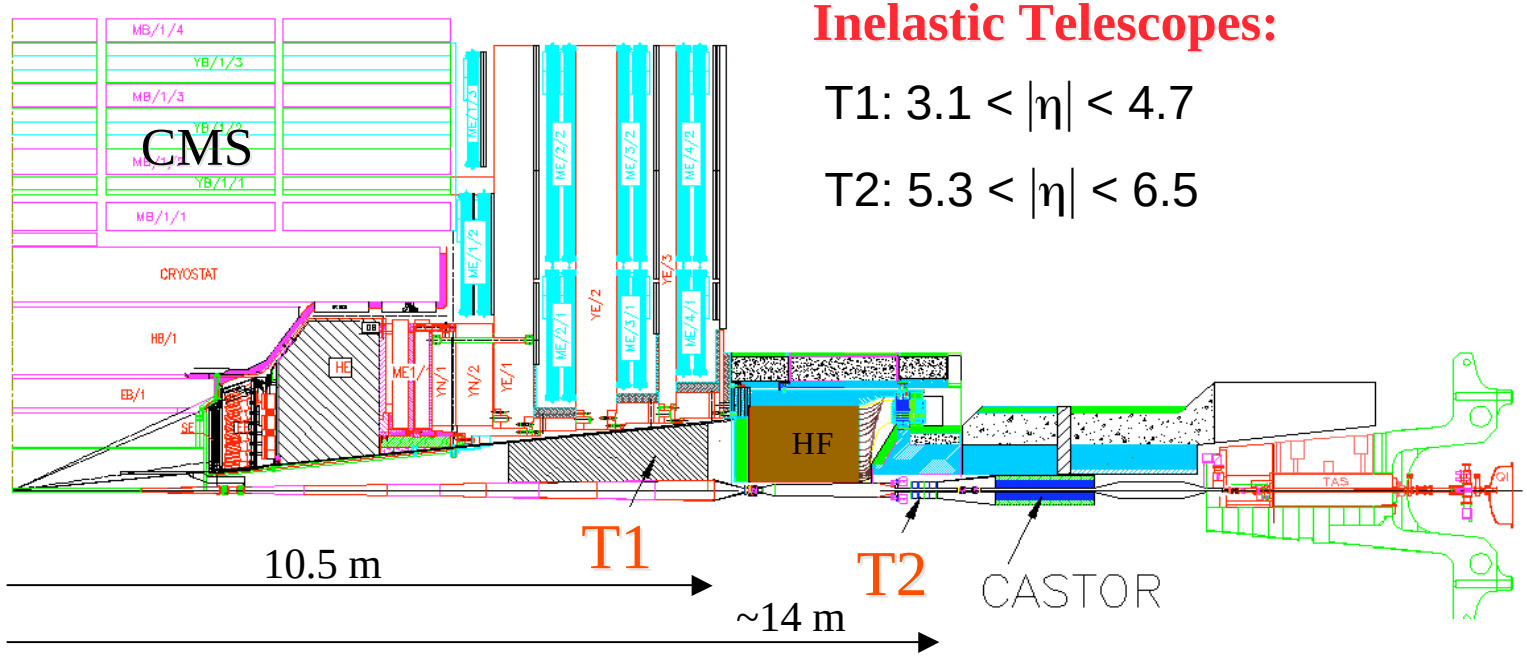
TOTEM will measure the complete range with good statistics

Experimental layout of TOTEM



Longest experiment at the LHC (440m)

The TOTEM Detectors

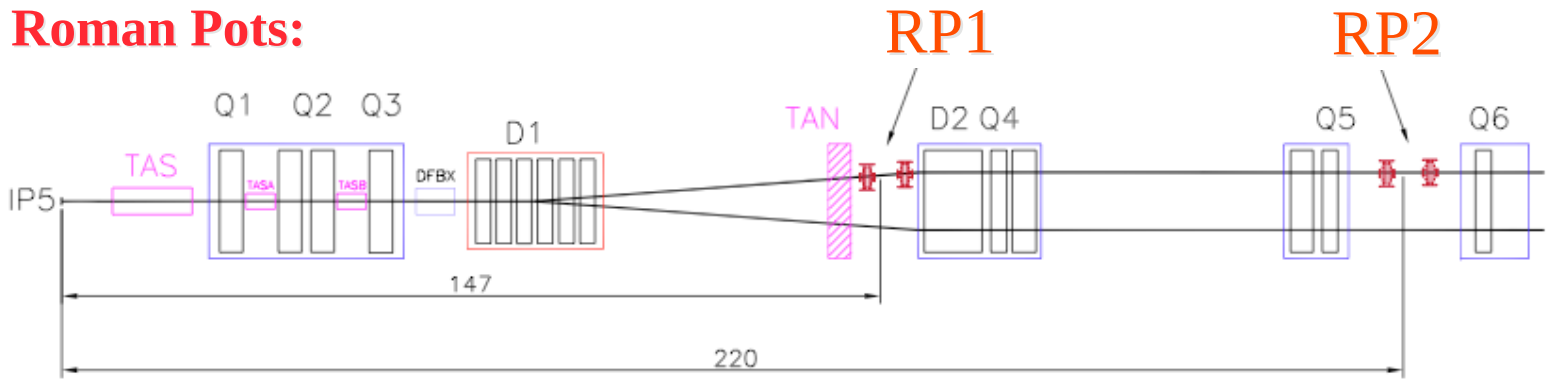


Inelastic Telescopes:

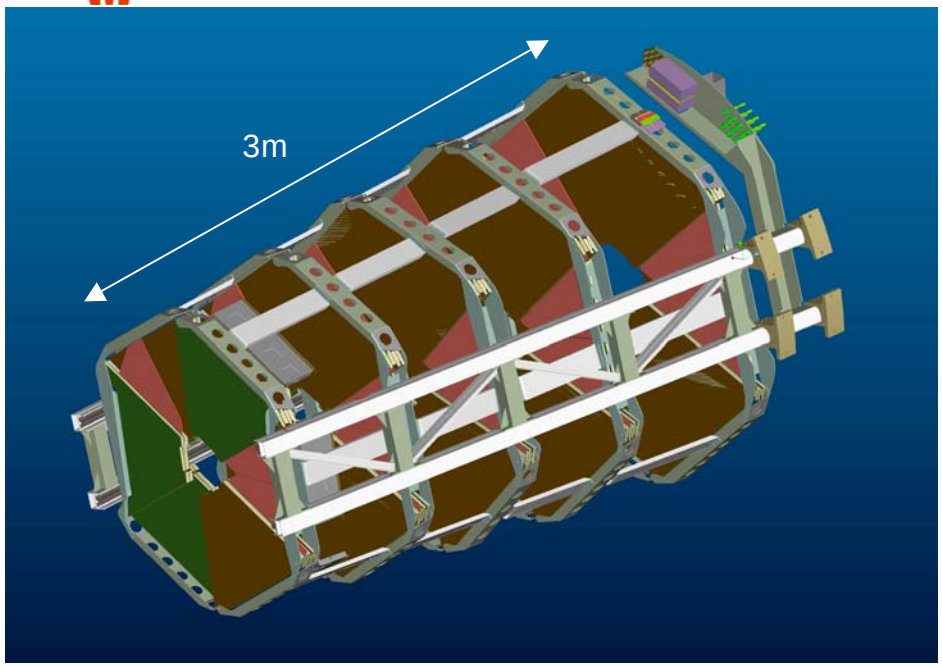
T1: $3.1 < |\eta| < 4.7$

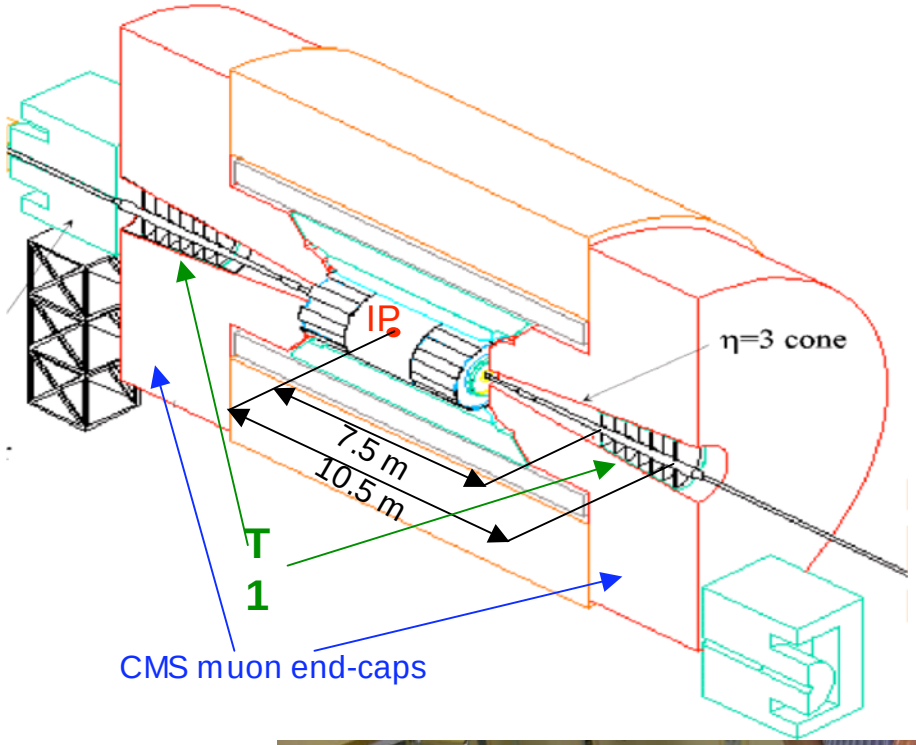
T2: $5.3 < |\eta| < 6.5$

Roman Pots:

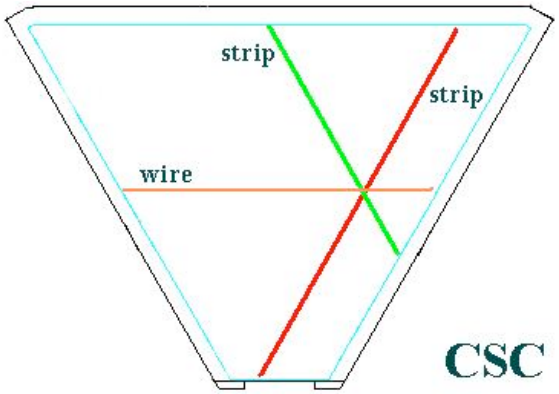


T1 telescope





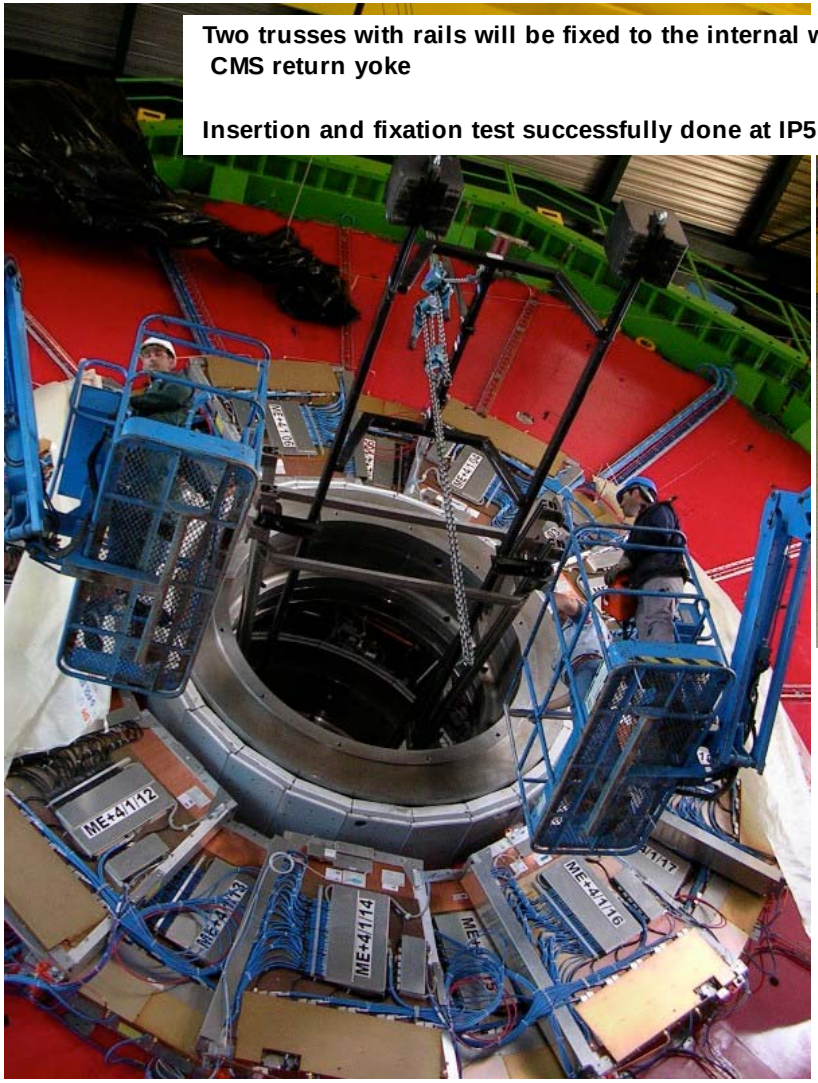
- Cathode Strip Chambers (CSC)
- 3.1 < |η| < 4.7
- 5 planes with measurement of 3 coordinates per plane
- 3 deg rotation and overlap between adjacent planes
- Primary vertex reconstruction allow background rejection
- Trigger with anode wires

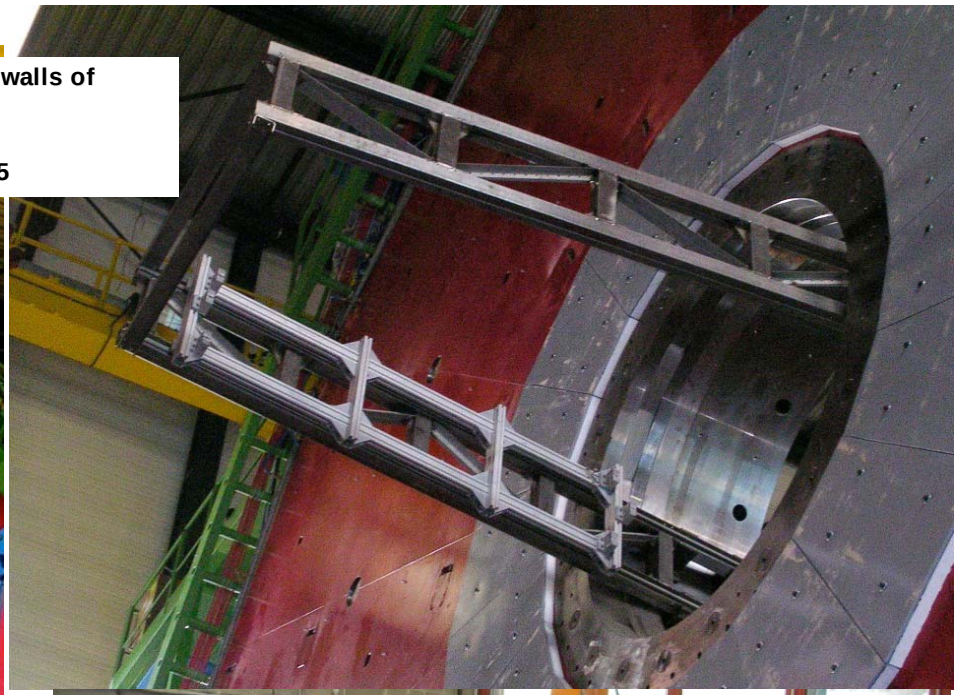


T1 support structure

Two trusses with rails will be fixed to the internal walls of CMS return yoke

Insertion and fixation test successfully done at IP5

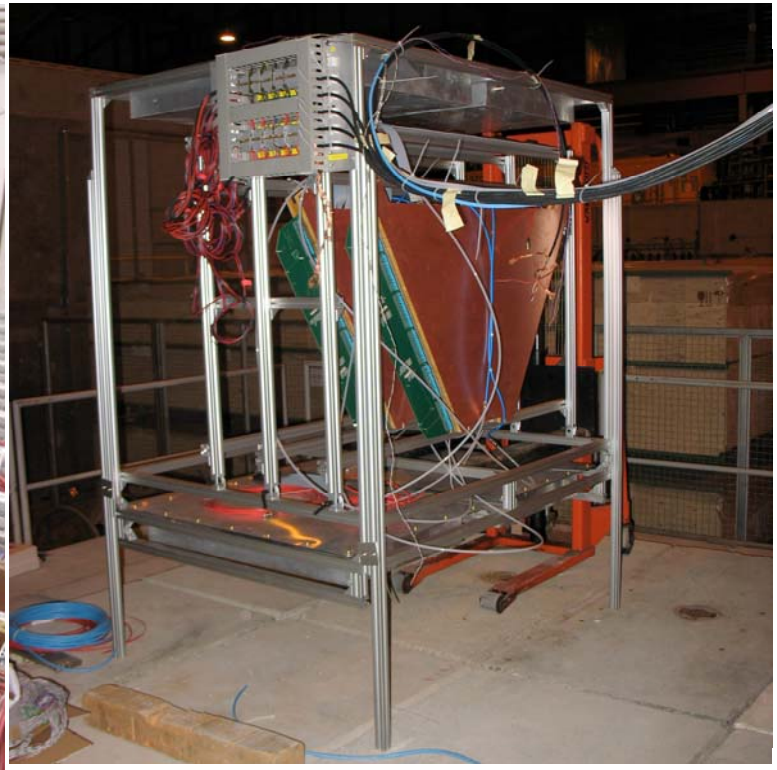




CSC mounted on frames will slide into final position

Mounting and sliding test of “half basket” performed at Genova

T1 Telescope



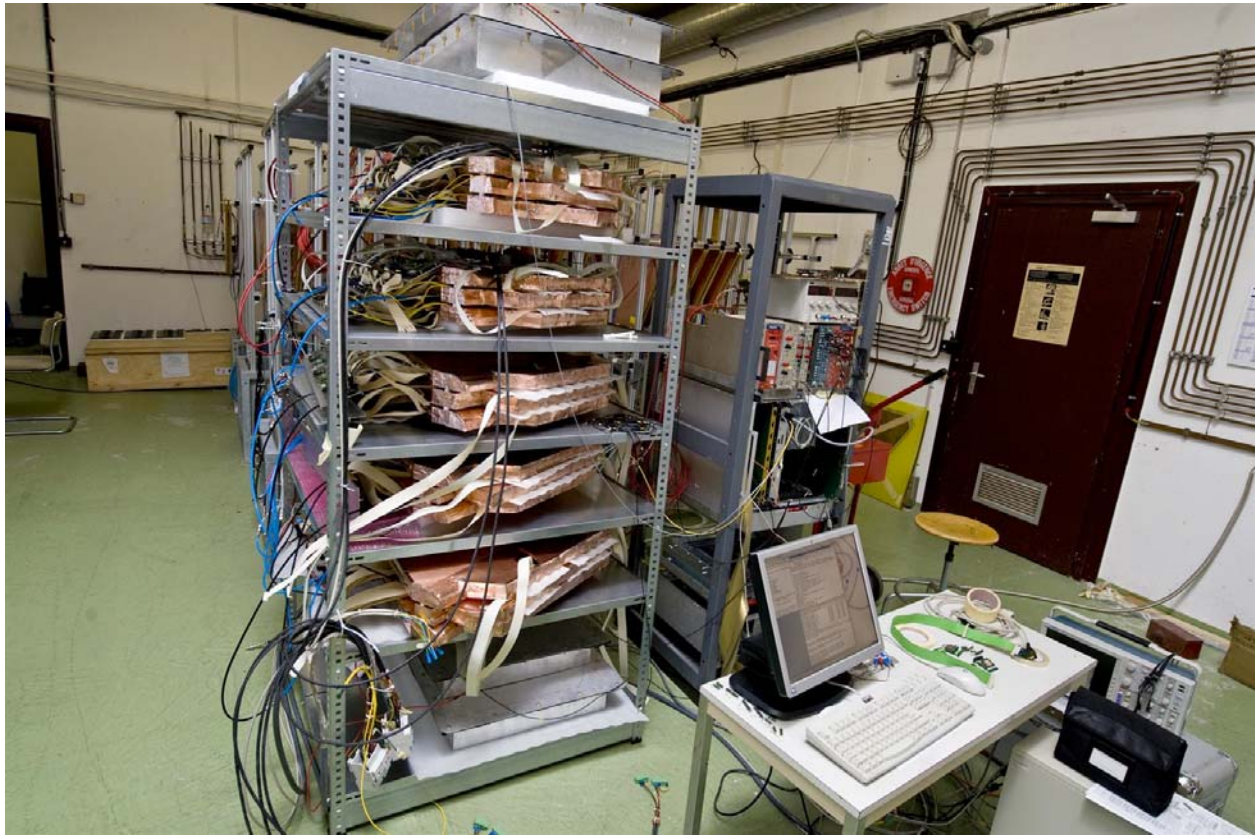
Ageing studies at the GIF: 12-month test with ~0.07 C/cm accumulated charge on wires corresponding to ~ 5 years at $L=10^{30}cm^{-2}s^{-1}$

Production at Gatchina (PNPI): 70 CSCs

Test and assembly done at CERN

Cosmic Ray test set-up

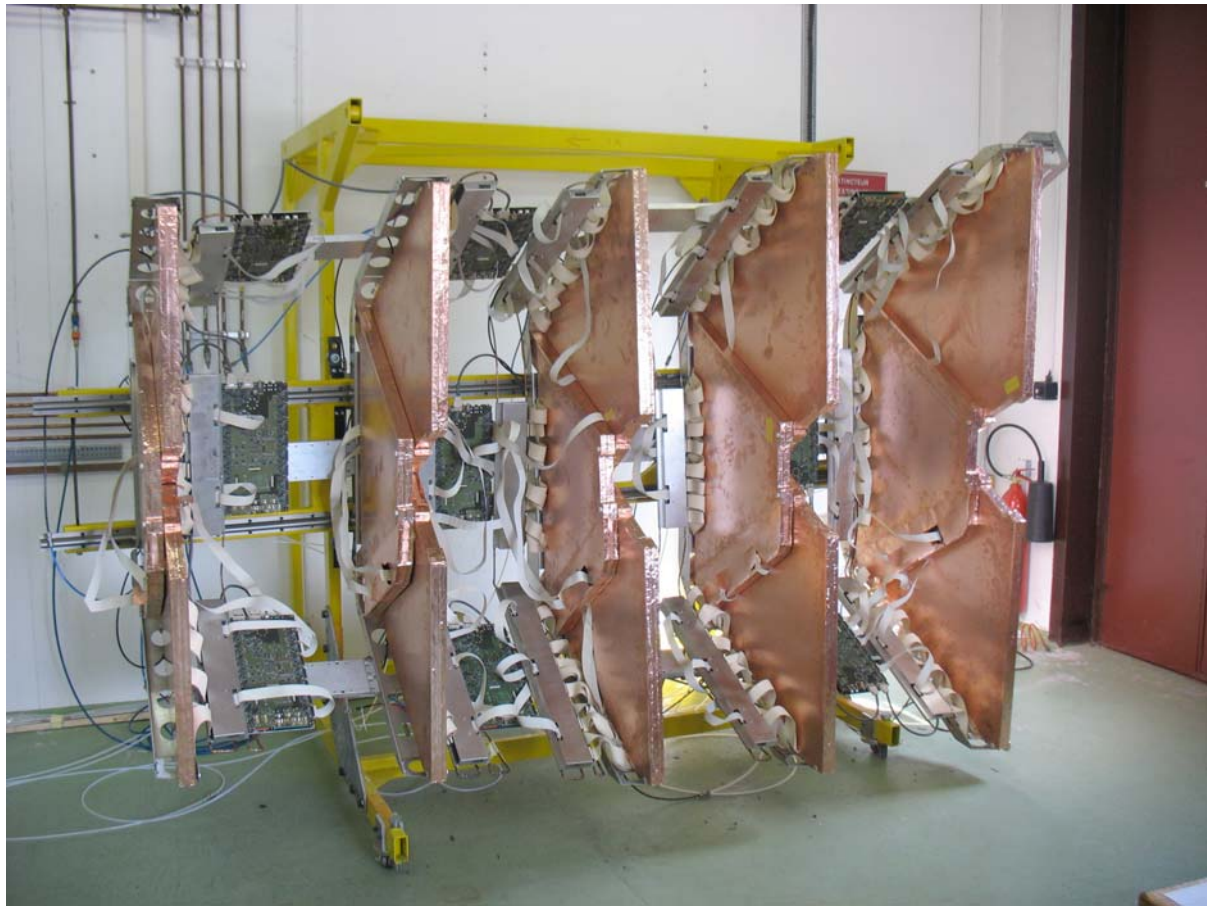
15 CSCs for first ¼ telescope



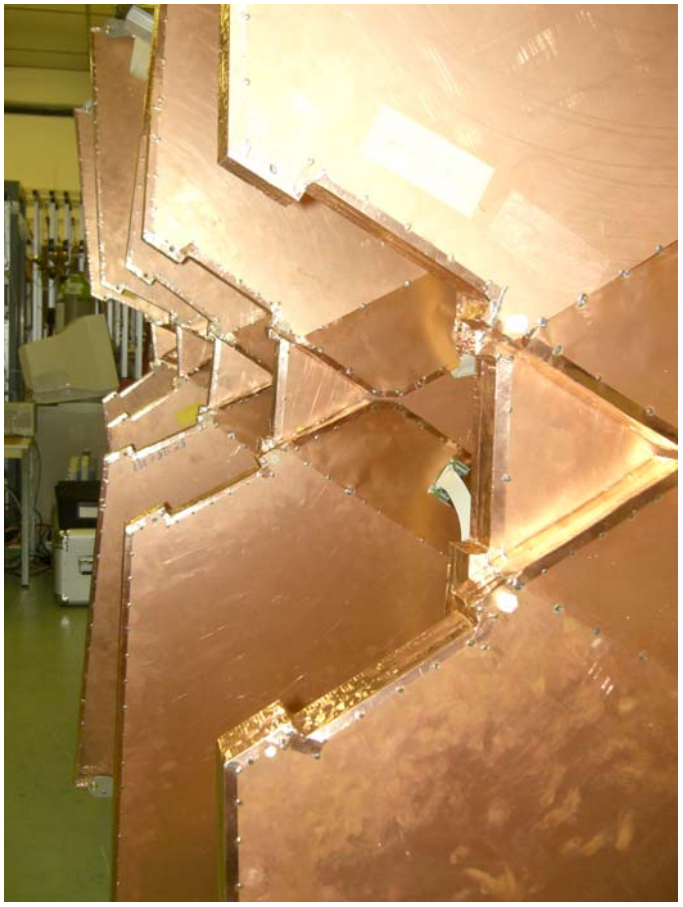
Even firemen help !!

¼ T1 Telescope complete with CSC chambers

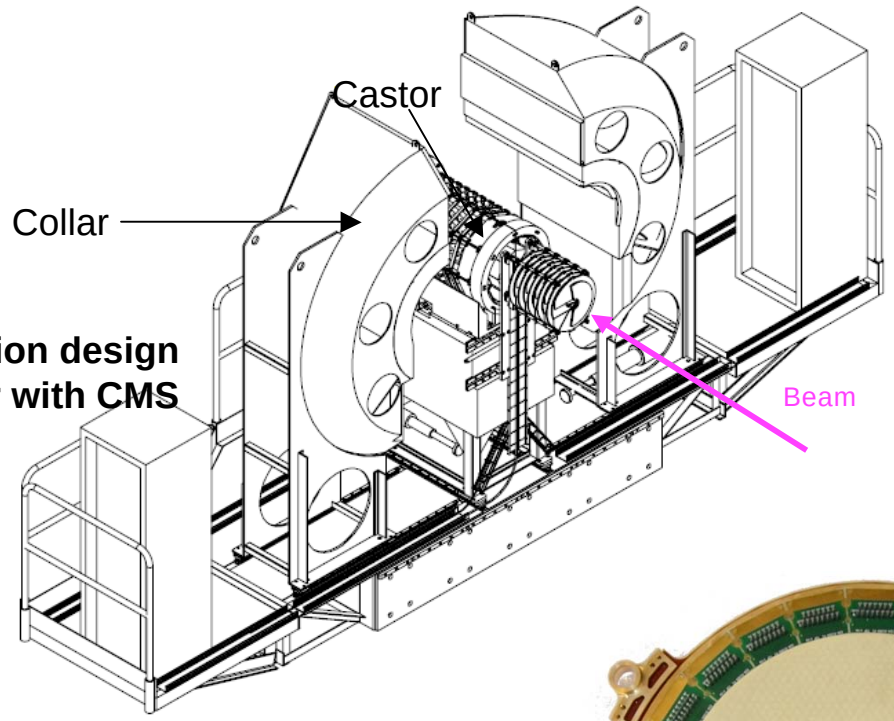
15 CSCs mounted 3 by 3



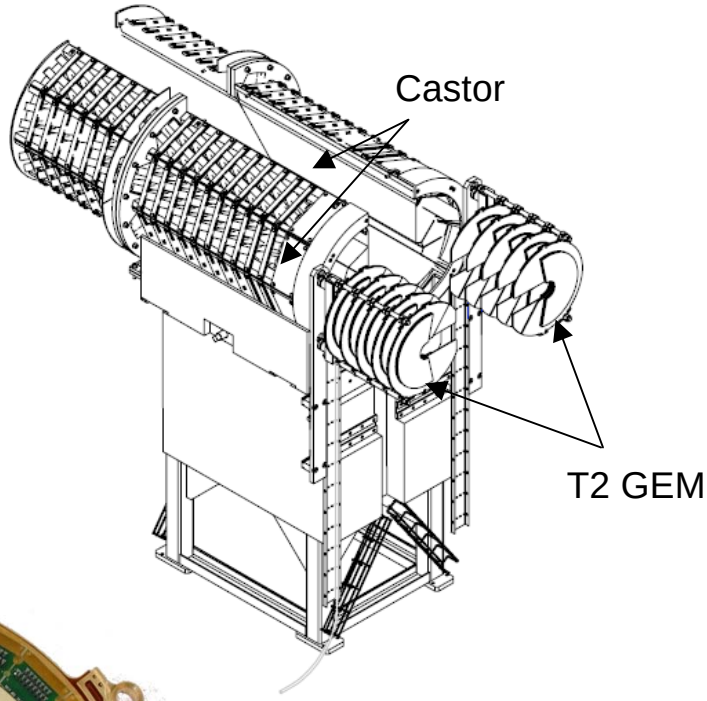
Tilt between layers

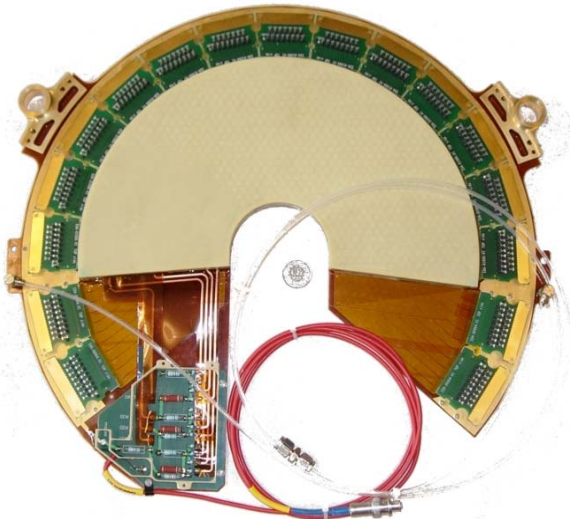


The T2 Telescope



Installation design together with CMS





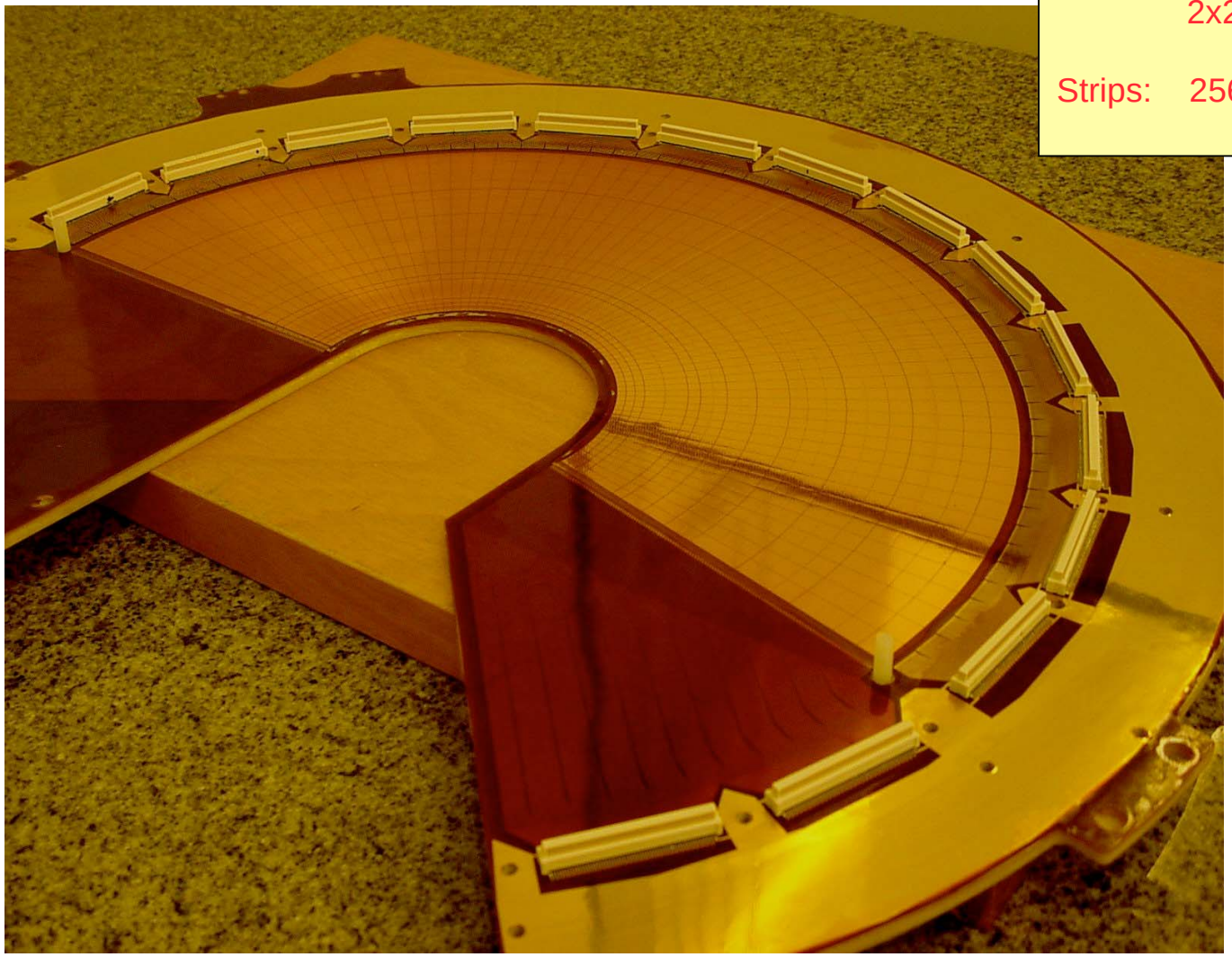
Final GEM chamber

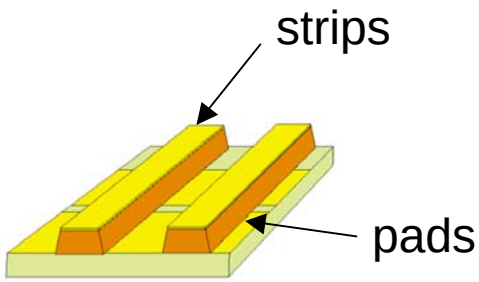
10 triple-GEM planes on each side of the IP to cope with high particle fluxes.

$5.3 < |\eta| < 6.6$

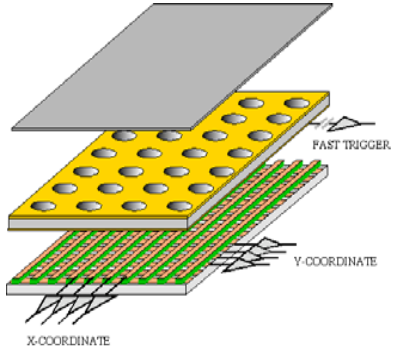
T2 Telescope (GEM)

Pads:	65(φ) x 24(η) = 1560 pads Δη x Δφ = 0.06 x 0.015π 2x2 mm^2 – 7x7 mm^2
Strips:	256 (width: 80 μm,pitch: 400 μm)



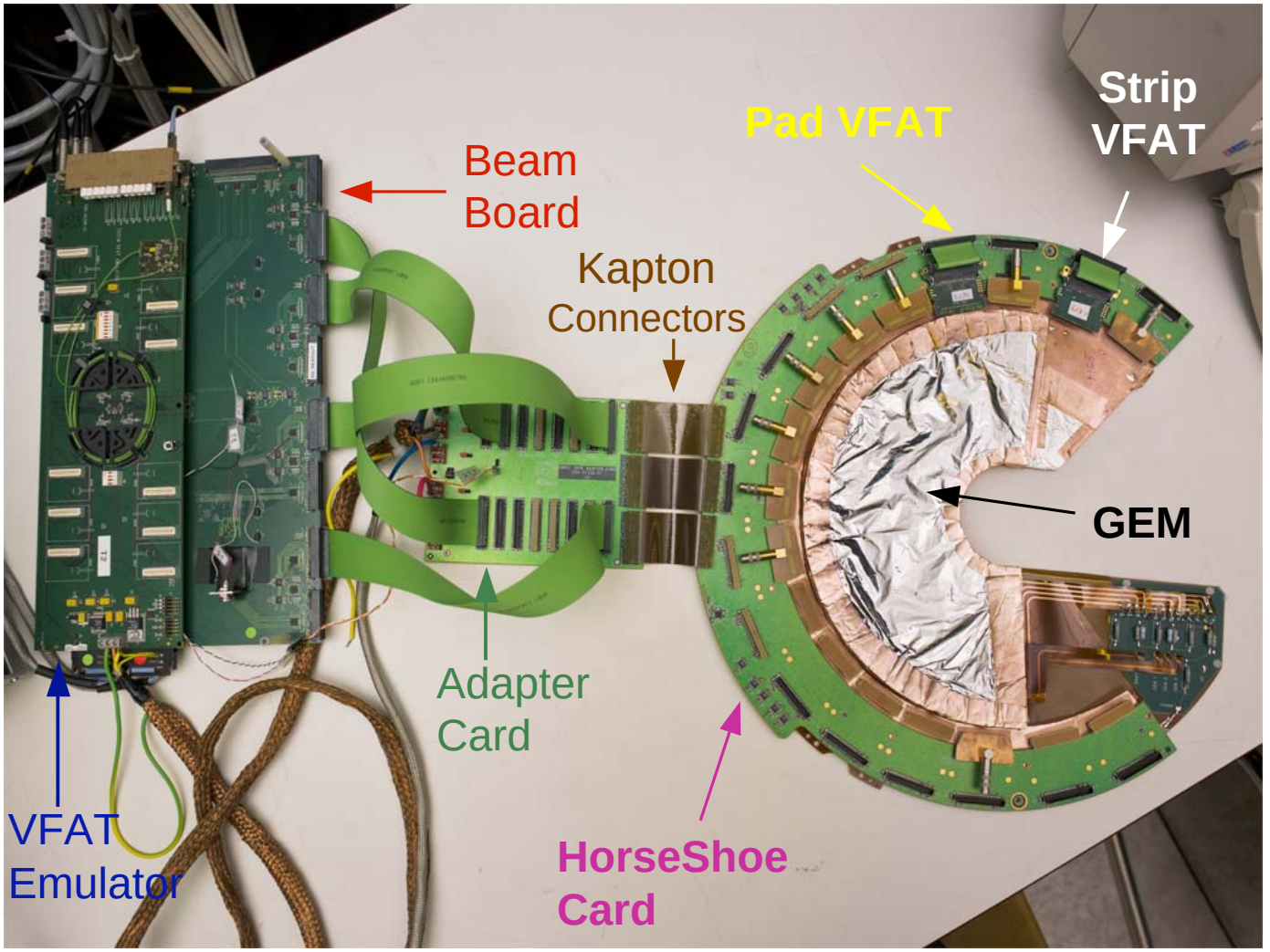


Technology used in COMPASS

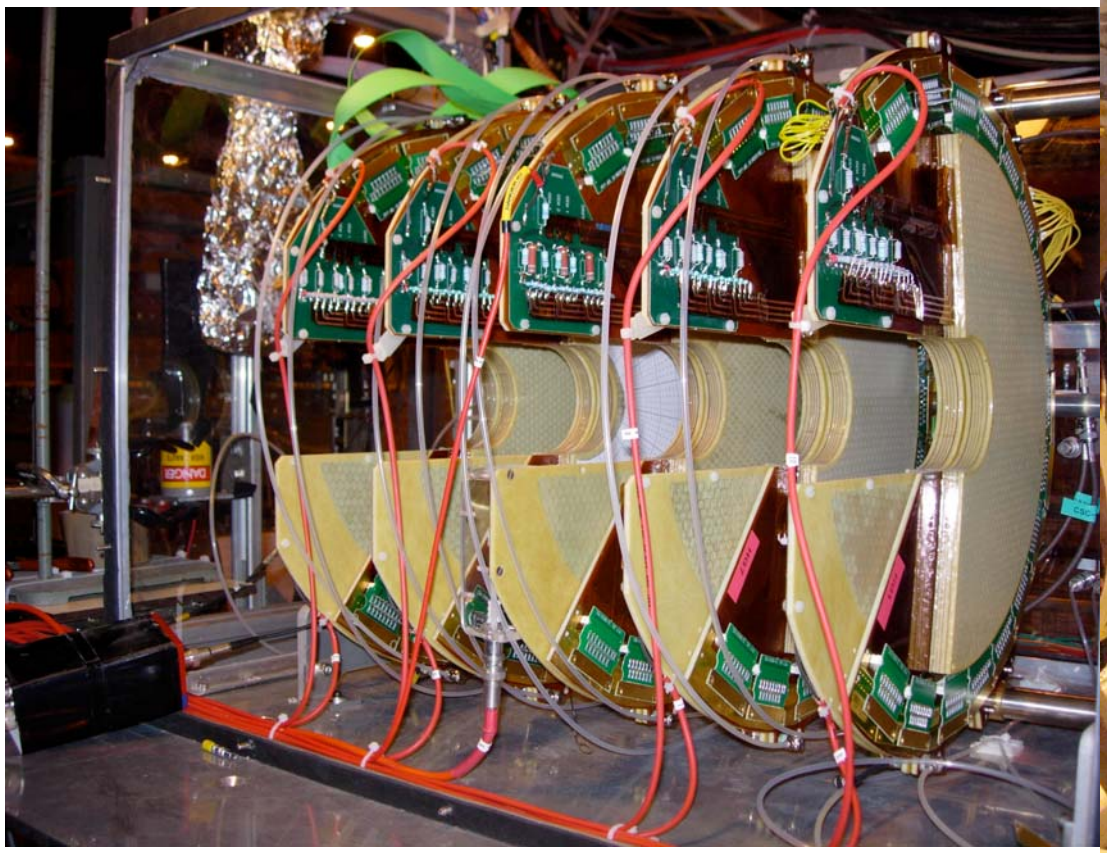


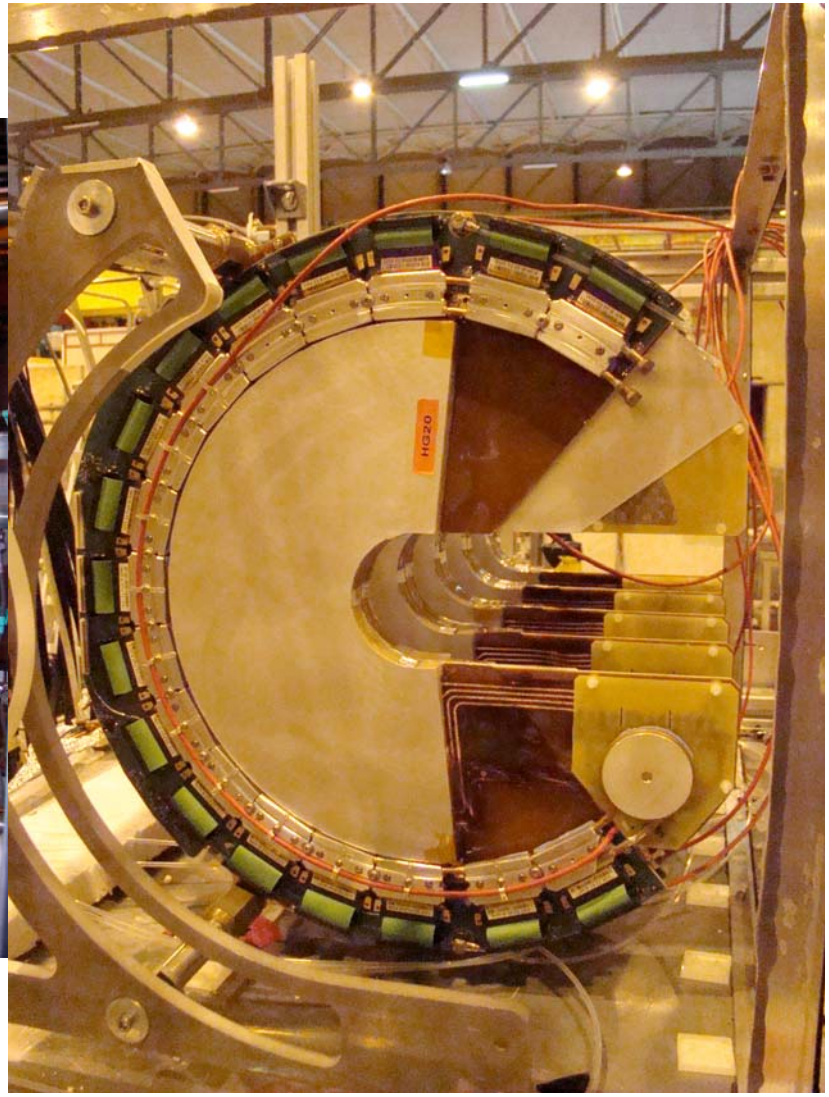
T2 and its Electronics

Lab setup:



T2 GEM Assembly

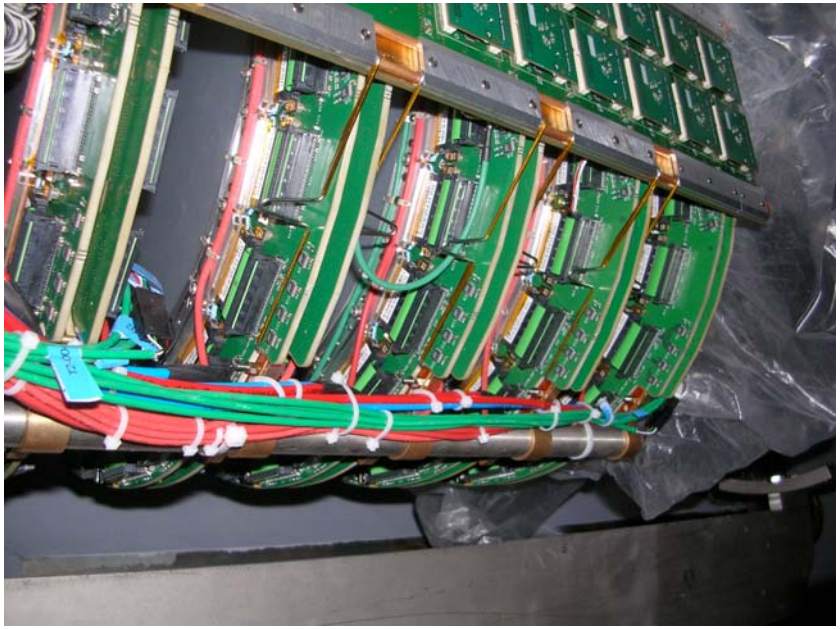




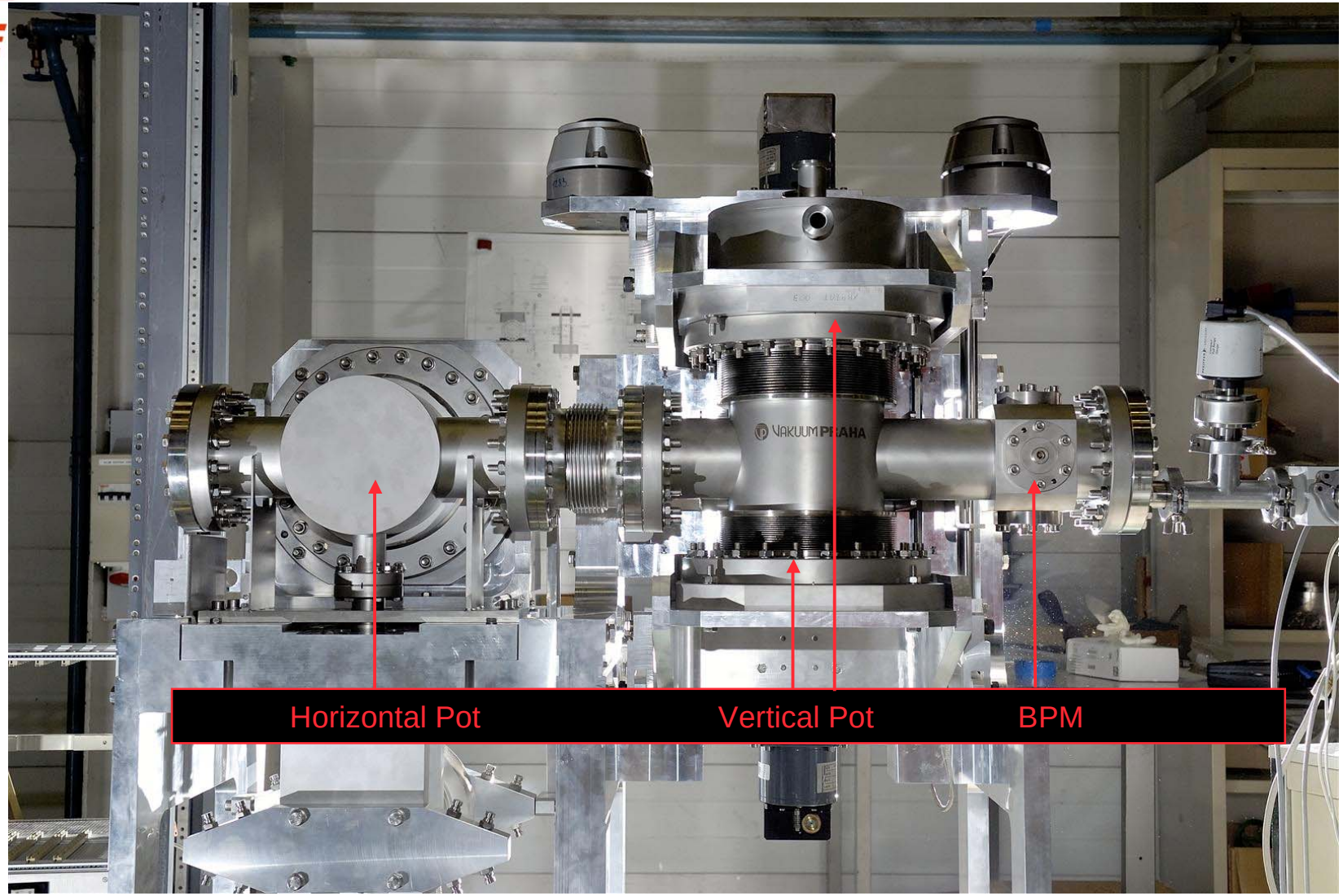
Production at Helsinki

Final assembly at CERN

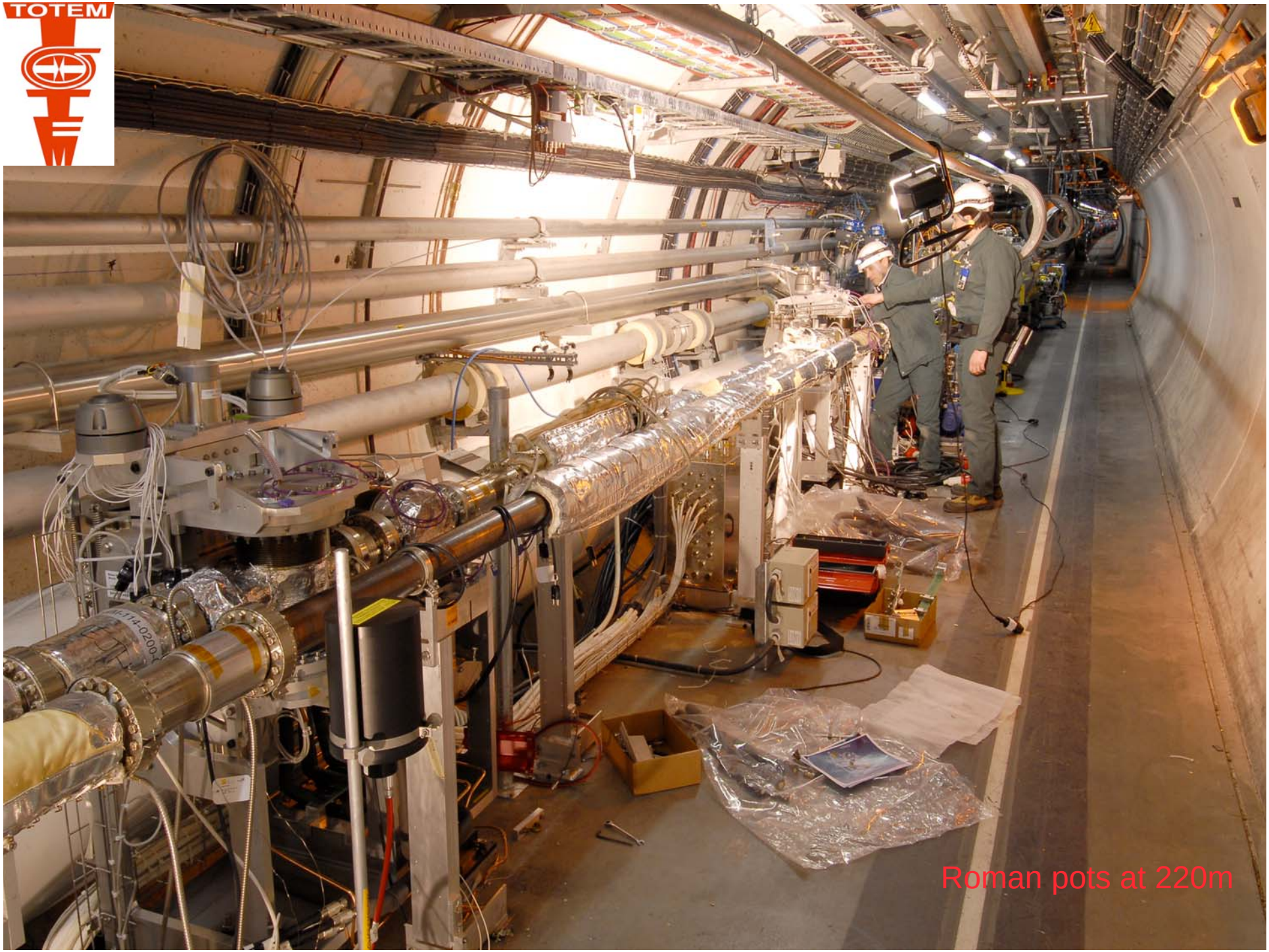
Installation of the T2 telescope in CMS

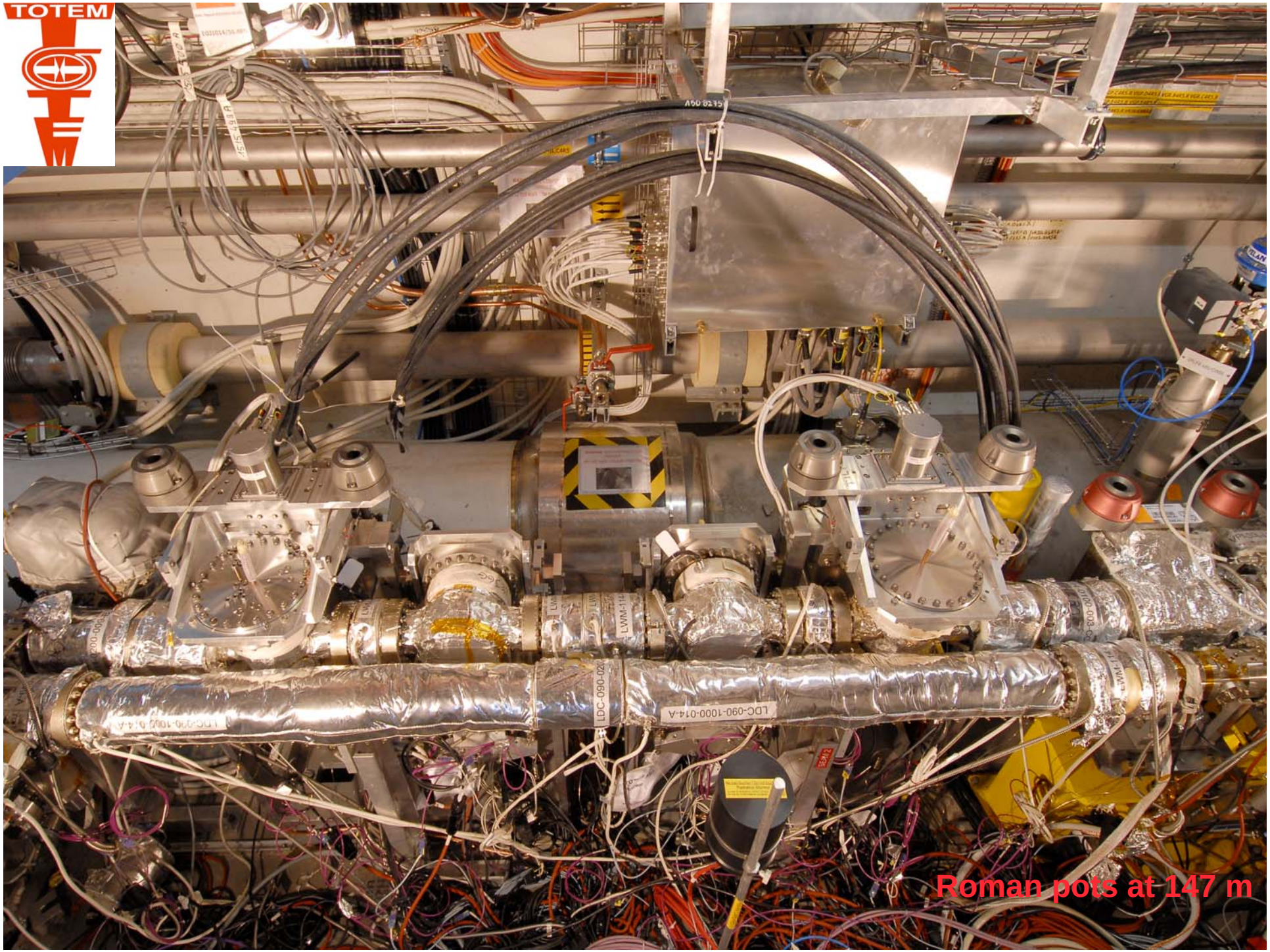


Roman Pot

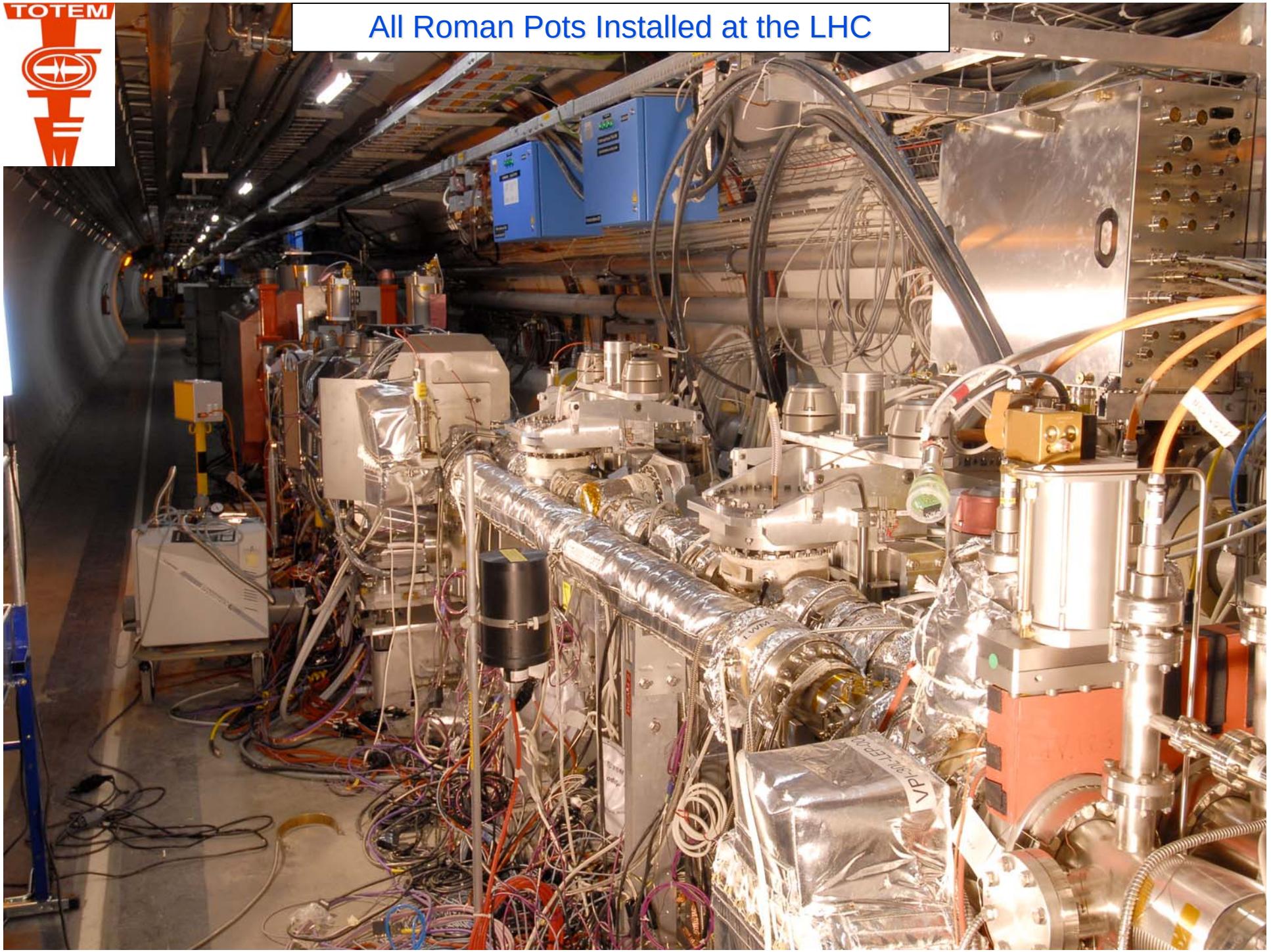


Mechanical rigid connections between horizontal and vertical pots and BPM important for alignment


TOTEM
Roman pots at 220m

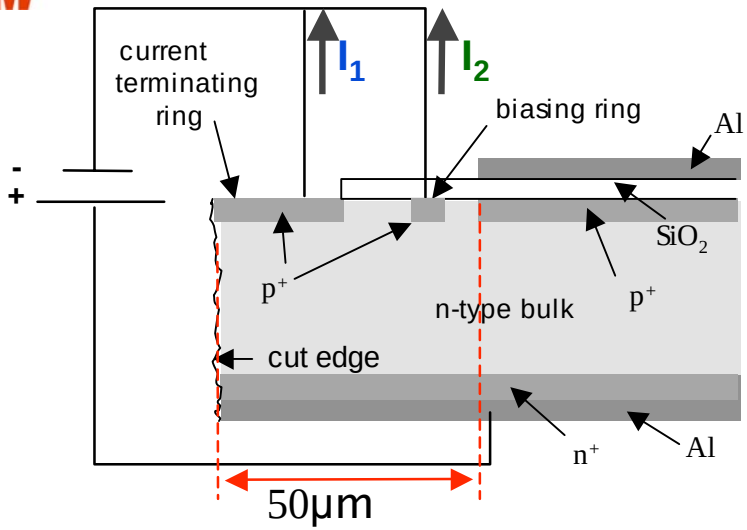

TOTEM
Roman pots at 147 m

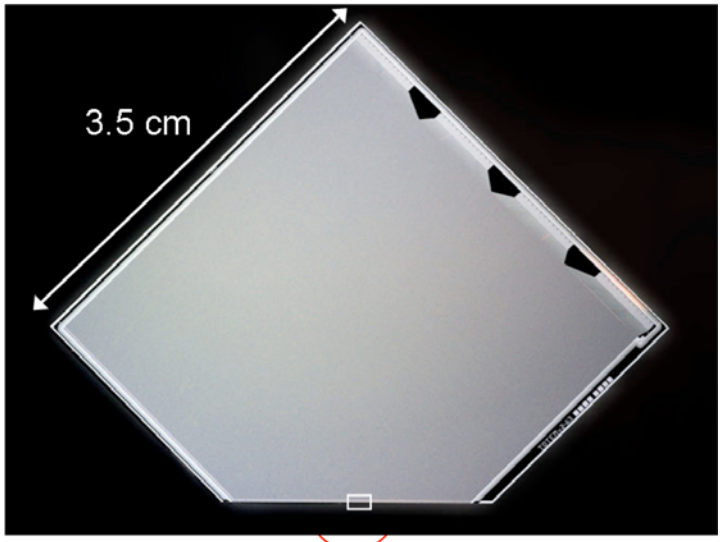
All Roman Pots Installed at the LHC

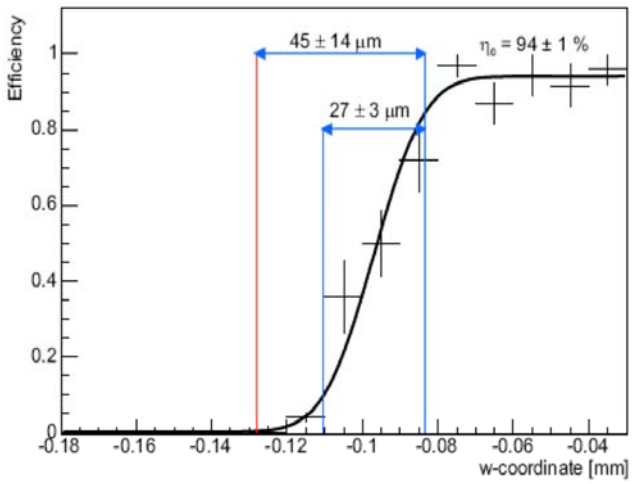


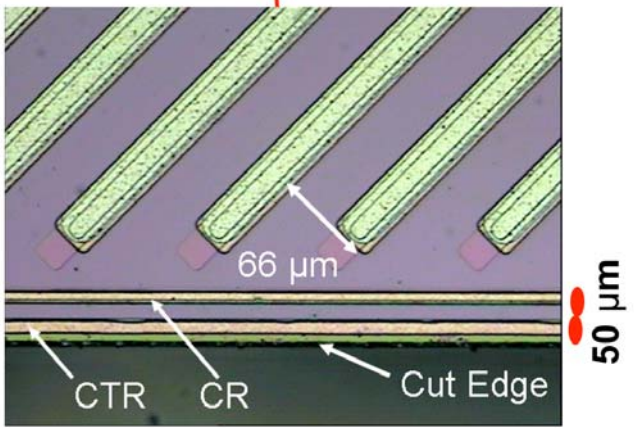
Si Edgeless Detectors for Roman Pots

Planar technology with CTS (Current Terminating Structure)

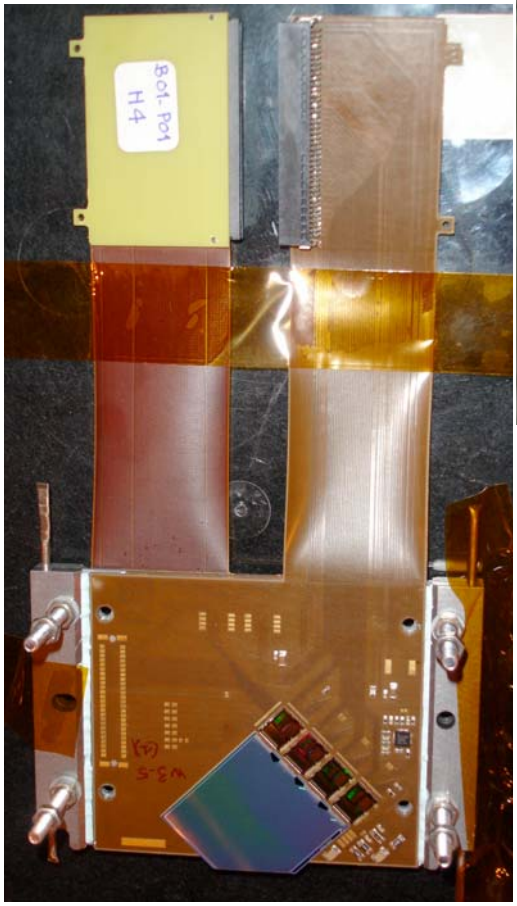




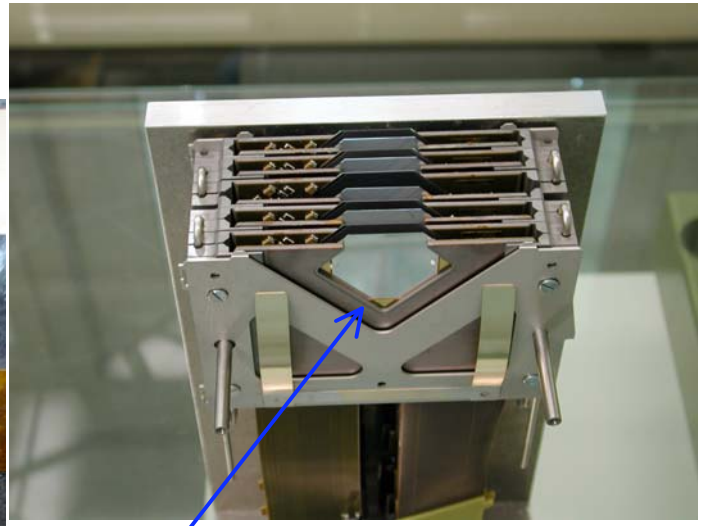




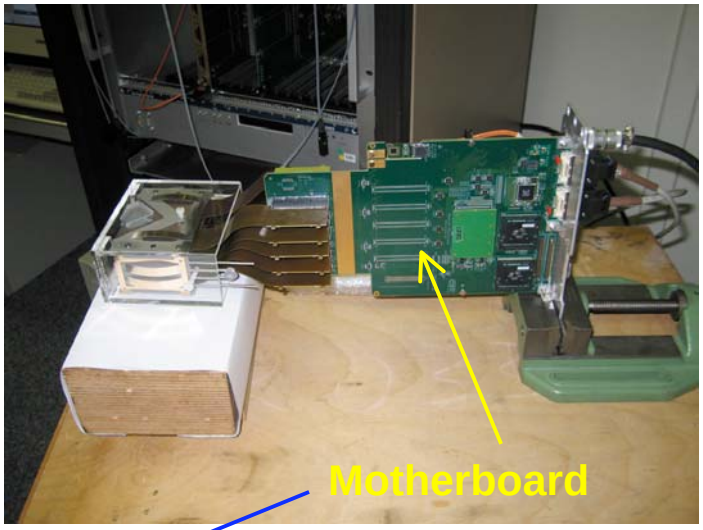
The Hybrid and the Assembly

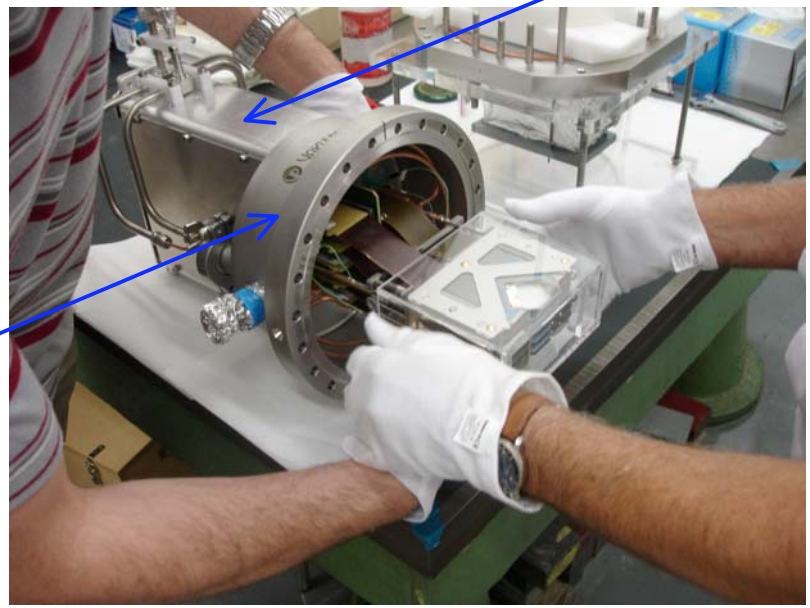


Kapton hybrids
laminated on CE7



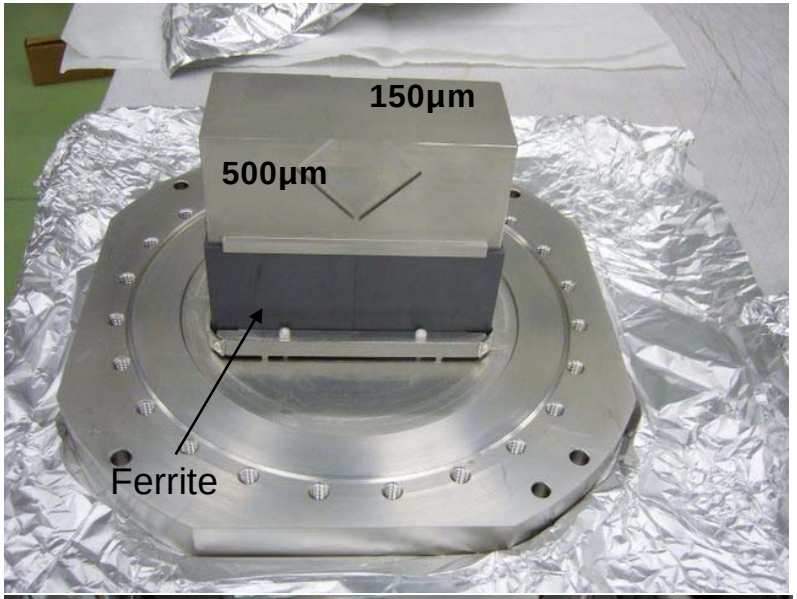
Assembly of
10 detectors

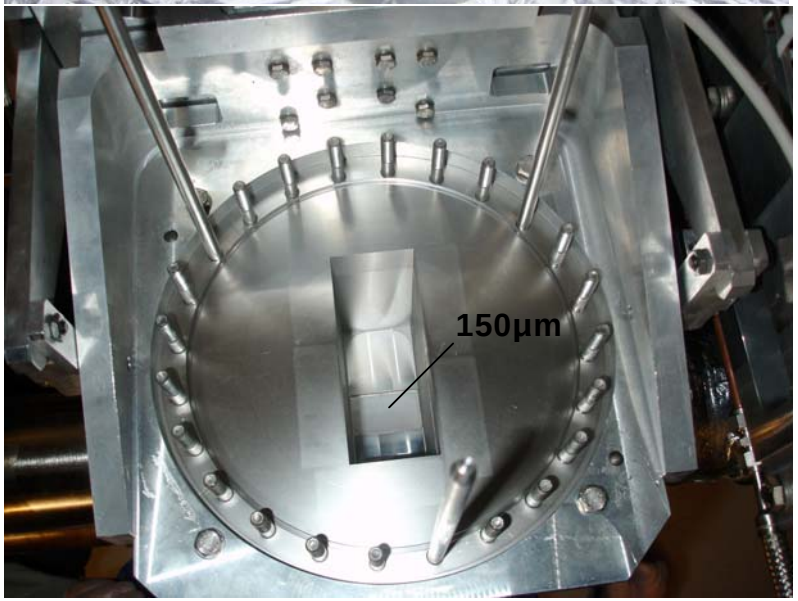


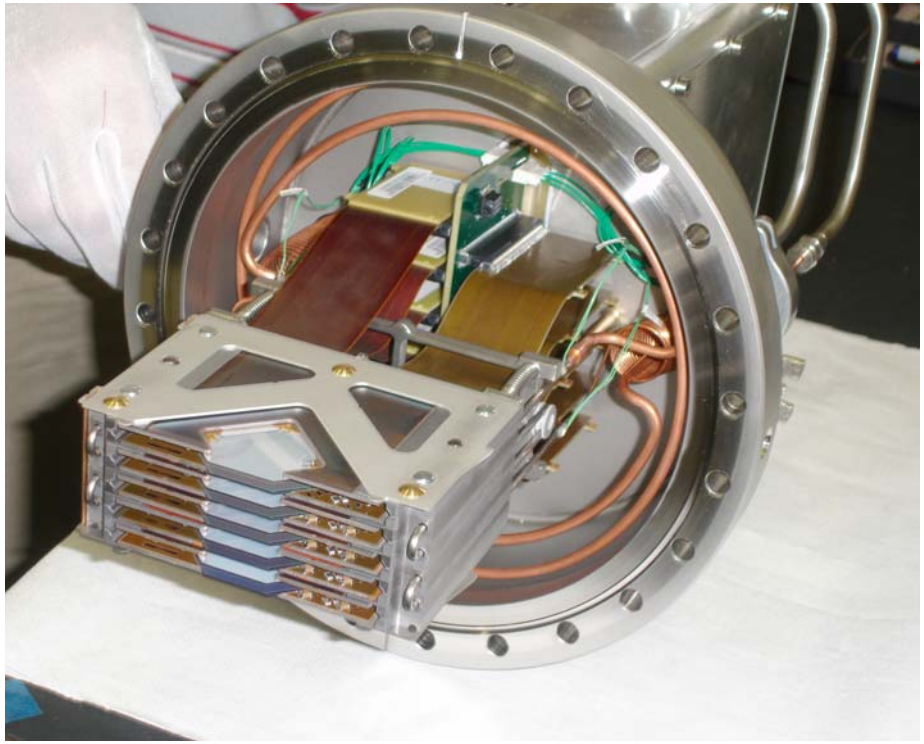


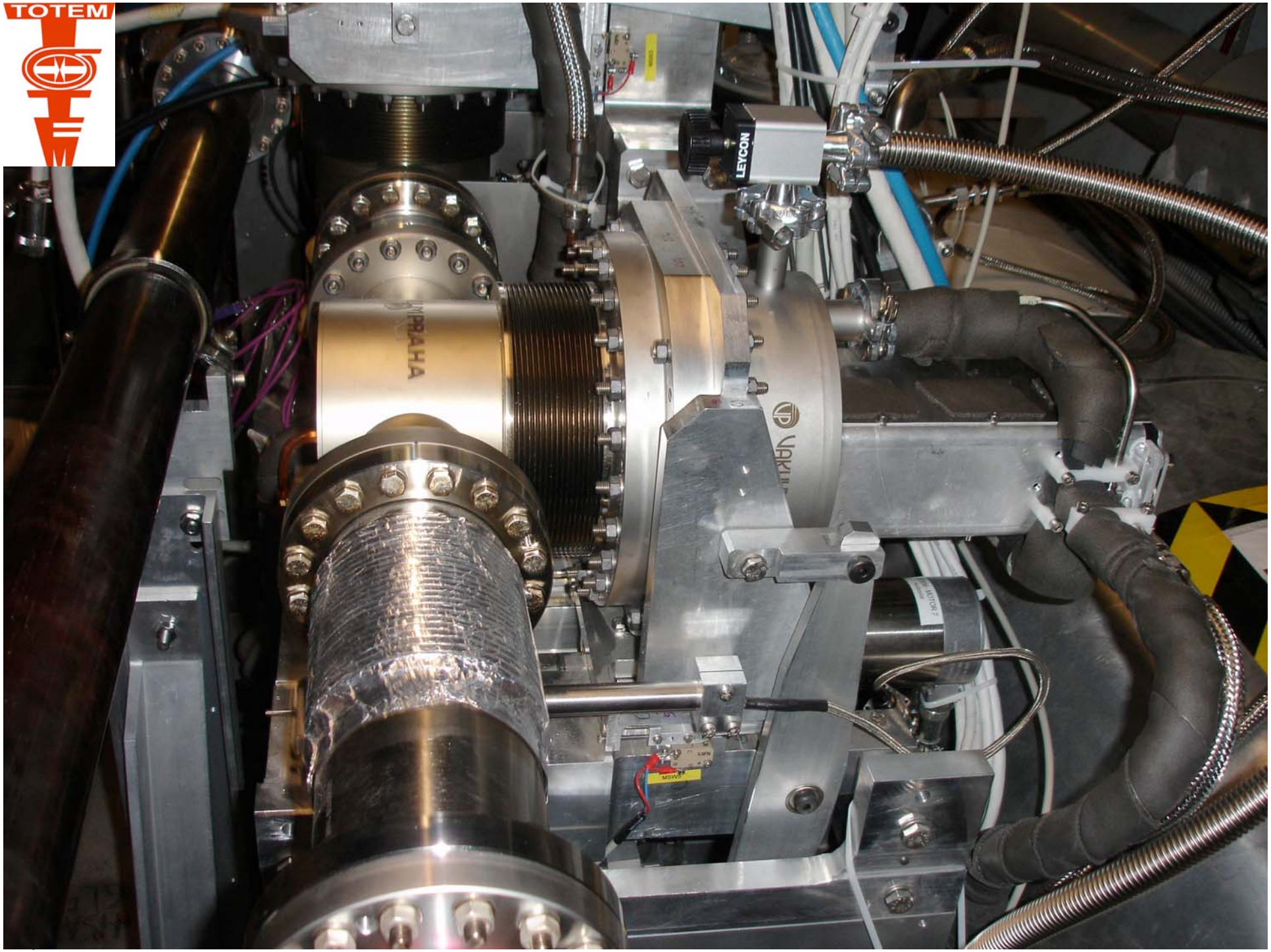
"Champignon"

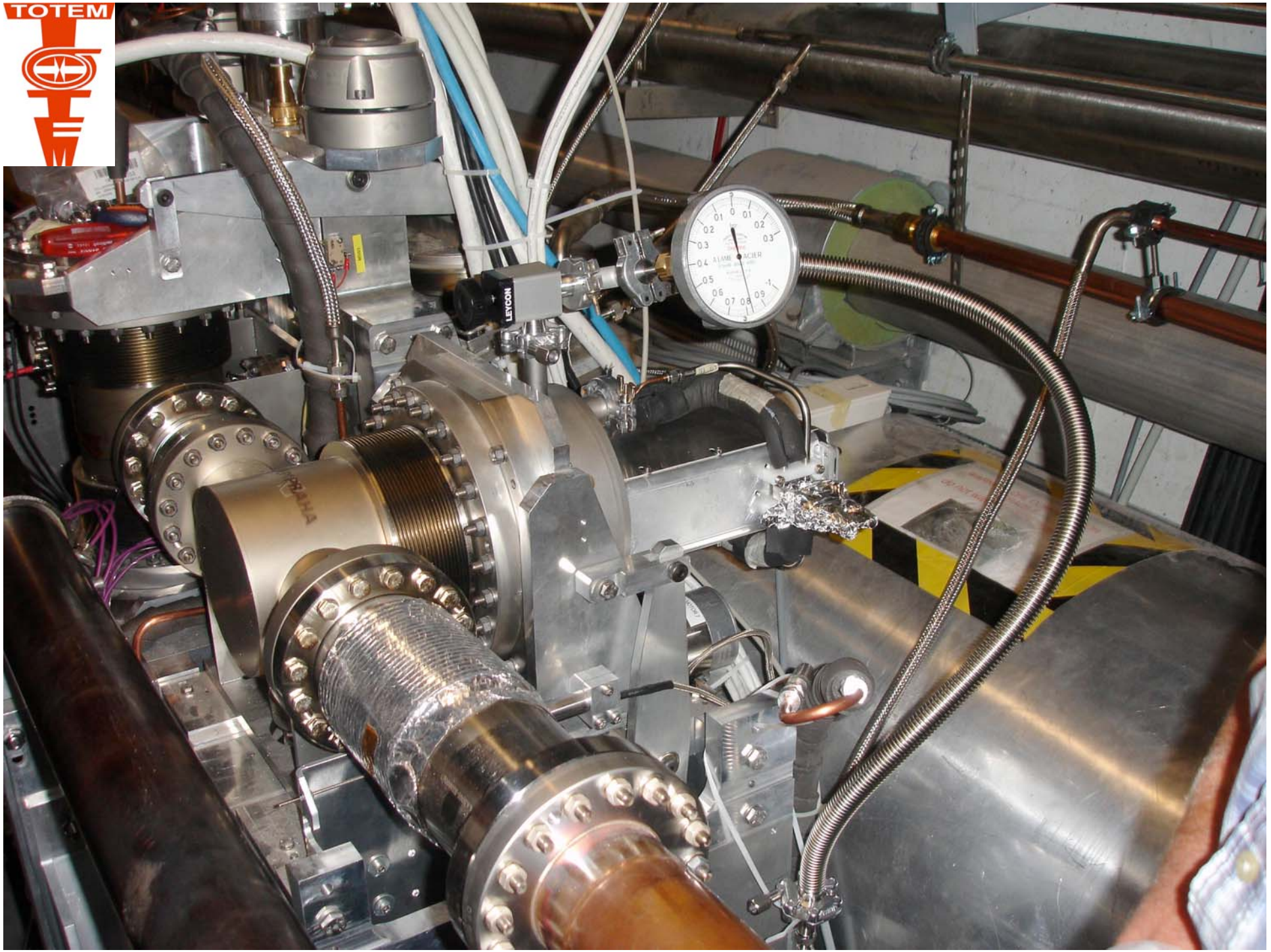
The window and the detector assembly





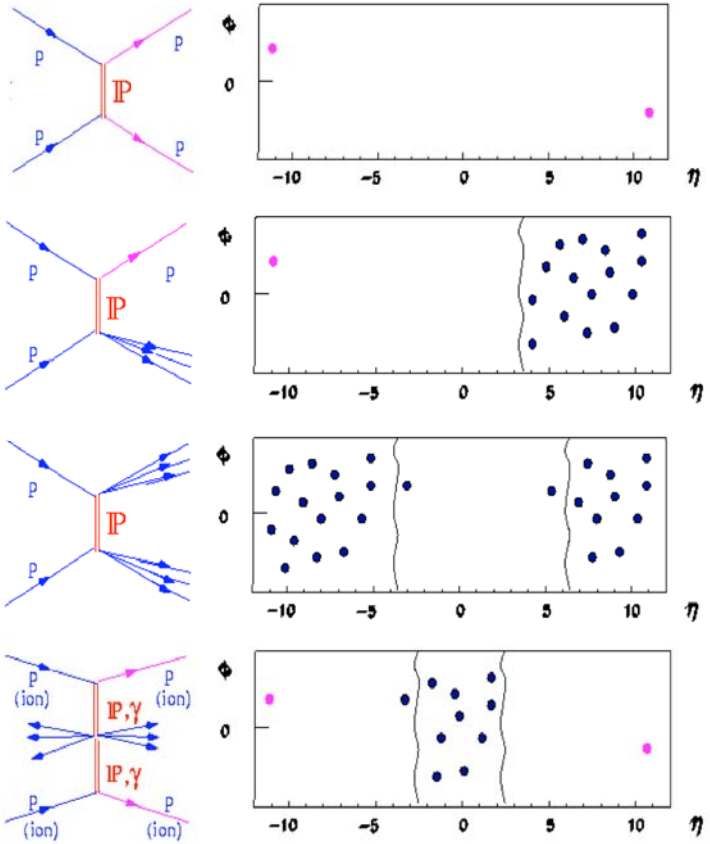



TOTEM
LEYCON
PRAHA


TOTEM
LEYBOLD

Level-1 Trigger Schemes at all run conditions

TOTEM trigger rate : few kHz adjusted to luminosities



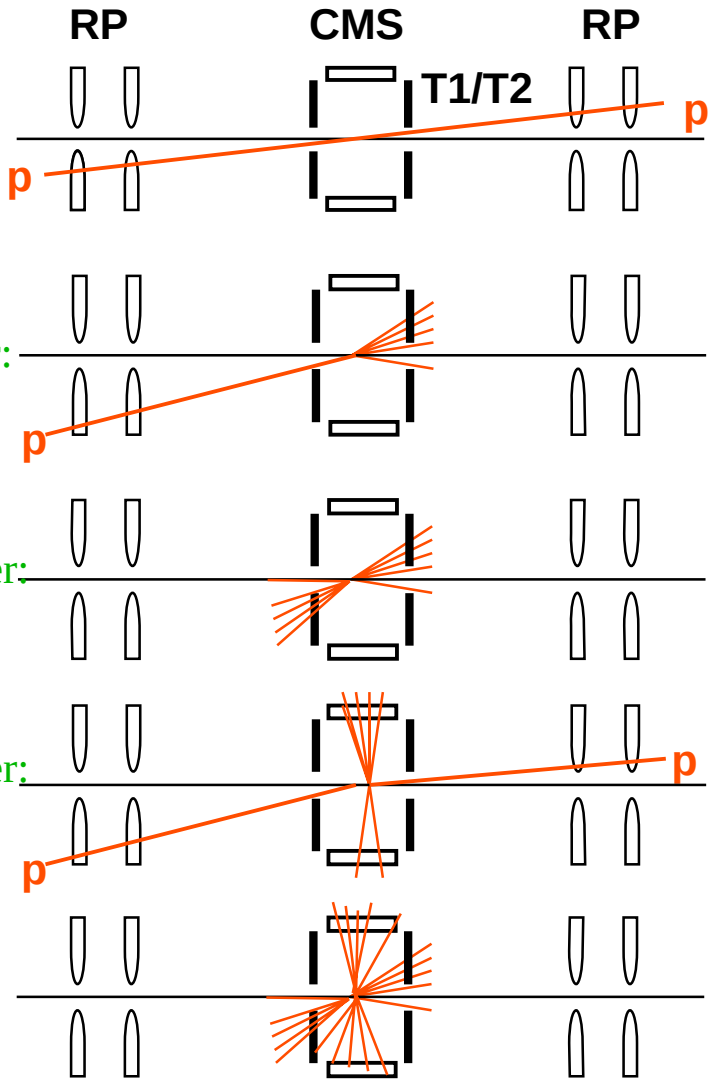
Elastic Trigger:

Single Diffractive Trigger:

Double Diffractive Trigger:

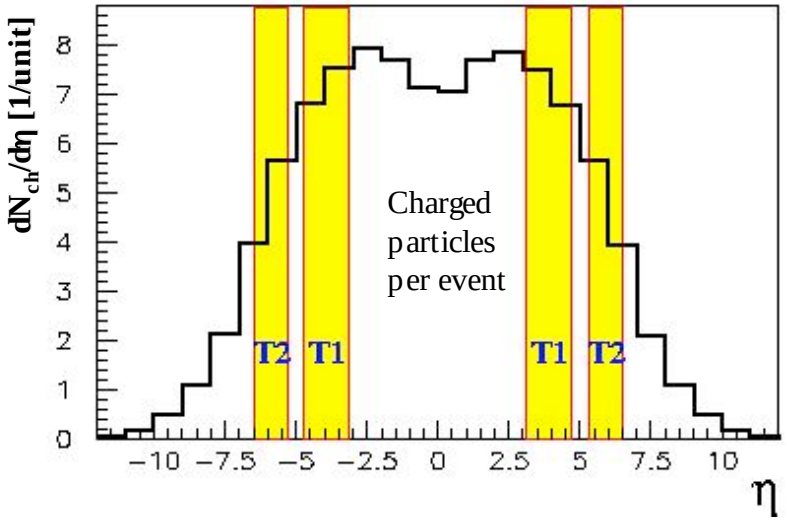
Central Diffractive Trigger:

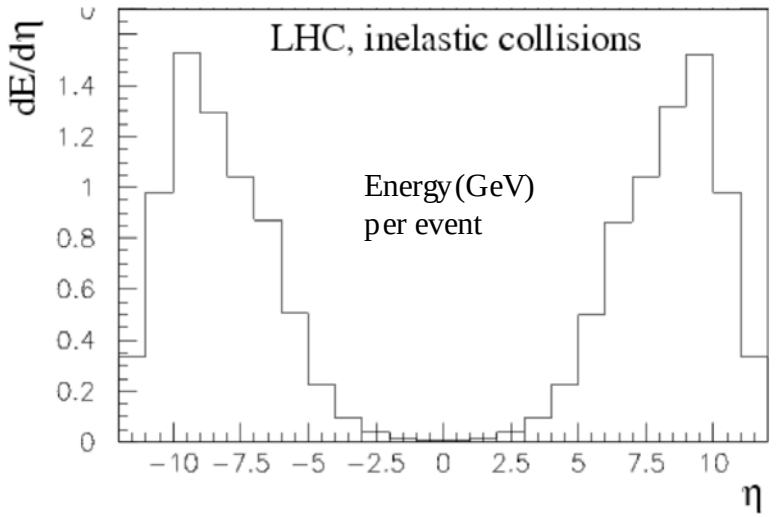
Minimum Bias Trigger:



η–Acceptance

non-diffractive minimum bias events





$\eta = - \ln \mathrm{tg}\, \theta/2$

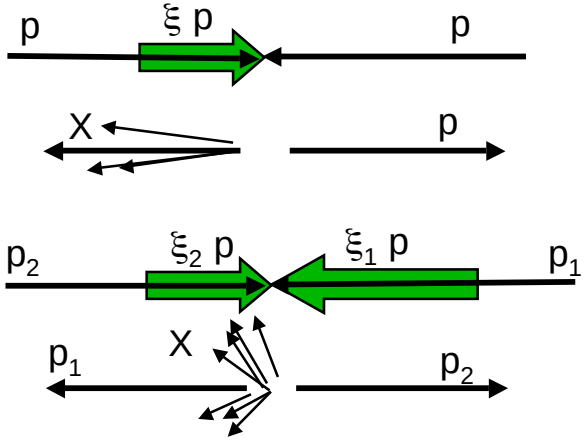
	σ [mb]	trigger loss [mb]	systematic error after extrapolations [mb]
Non-diffractive inelastic	58	0.06	0.06
Single diffractive	14	3	0.6
Double diffractive	7	0.3	0.1
Double Pomeron	1	0.2	0.02
Total	80	3.6	0.8

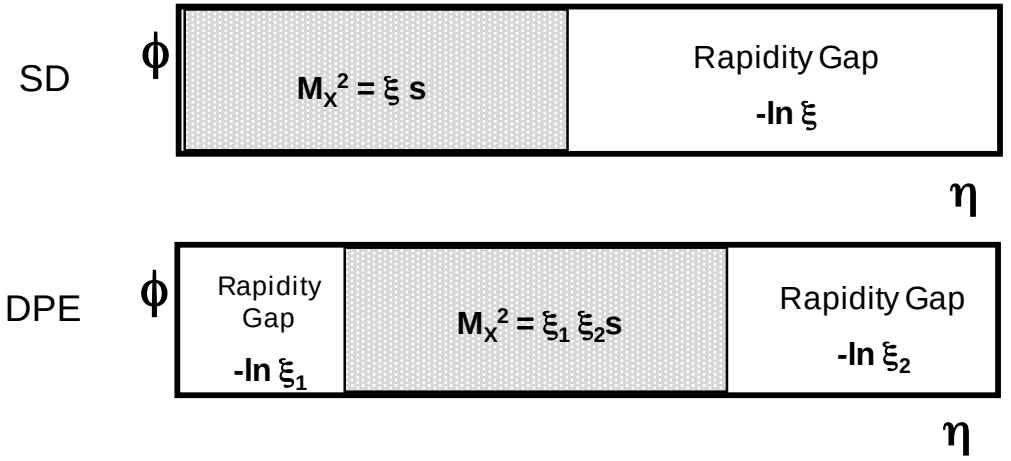
All detectors with trigger capability

Trigger acceptance > 95%

for all inelastic events

Soft Diffraction





- **Measure ξ**
- **Compare with rap gap Δη = -lnξ**

  gap suppression
- **Cross-section σ (ξ,t)**

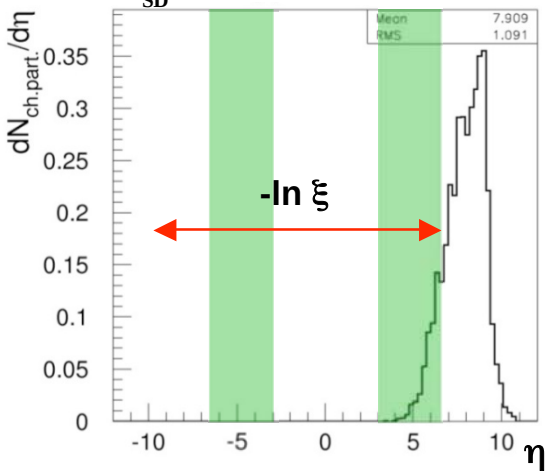
$$\left(\frac{d\sigma}{d\Delta\eta}\right)_{t=0} \approx \text{constant} \Rightarrow \frac{d\sigma}{dM^2} \sim \frac{1}{M^2} \Rightarrow \frac{d\sigma}{d\xi} \sim \frac{1}{\xi}$$

Signatures of Single Diffractive Events

$\xi = \Delta p / p$

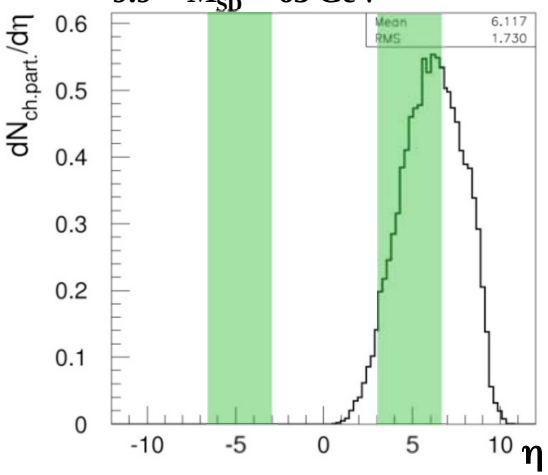
$\ln \xi < -14.5$

$M_{SD} < 9.9$ GeV



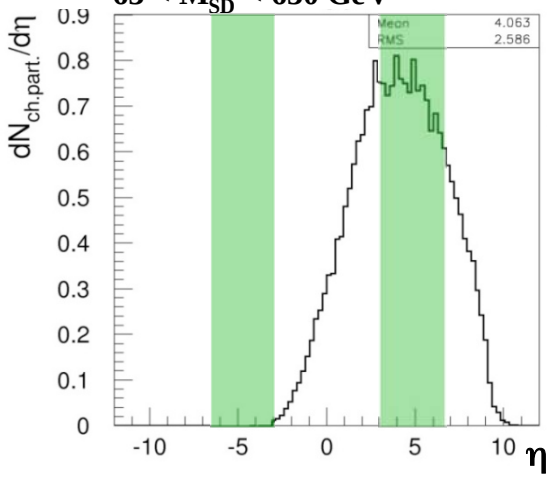
$-14.5 < \ln \xi < -10.8$

$9.9 < M_{SD} < 63$ GeV



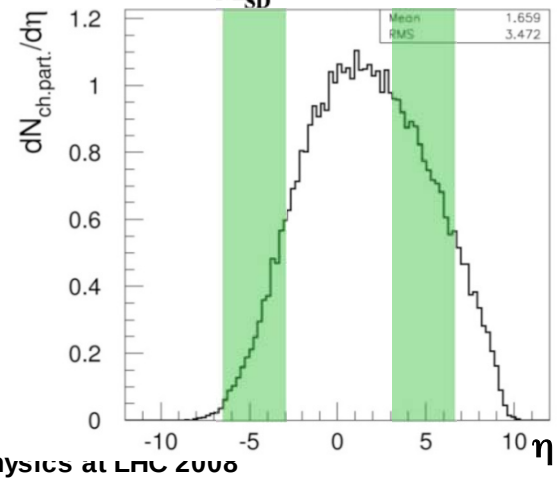
$-10.8 < \ln \xi < -6.2$

$63 < M_{SD} < 630$ GeV



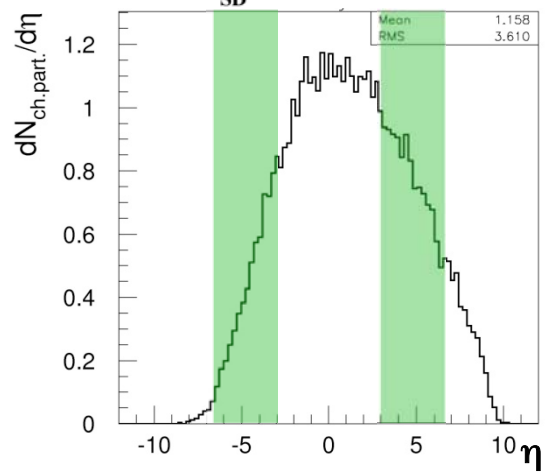
$-6.2 < \ln \xi < -1.6$

$0.63 < M_{SD} < 6.3$ TeV



$-3.9 < \ln \xi < -1.6$

$2.0 < M_{SD} < 6.3$ TeV



Typical individual cross-sections:

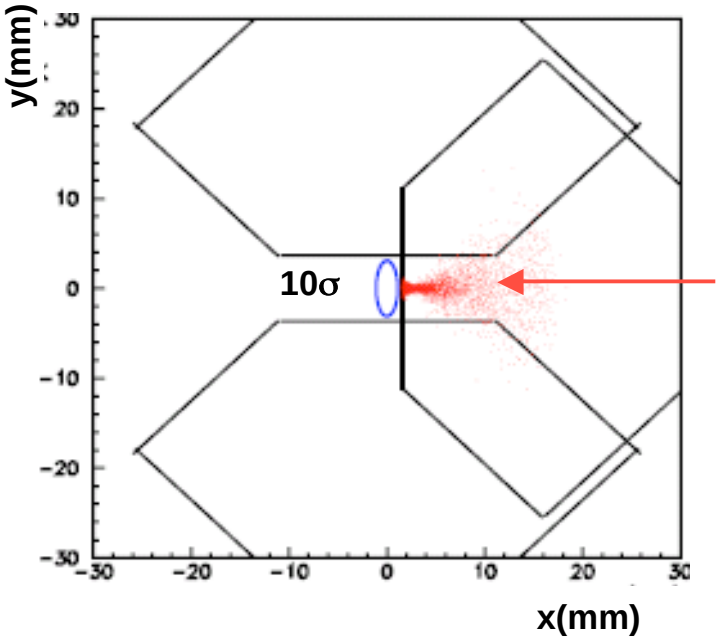
$\sigma \sim 1 - 2$ mb

Multiplicity distributions are difficult

Measurement of Forward Protons: the principle

Diffractive protons : hit distribution @ RP220

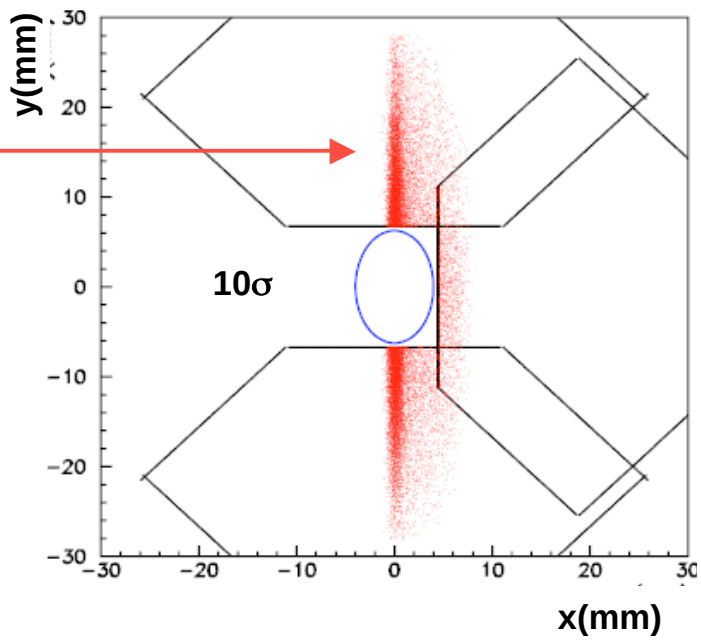
low β = 0.5 - 2 m



$y \sim \Theta_y^{scatt} \sim |t_y|^{1/2}$

$x \sim \xi = \Delta p/p$

high β = 90 m



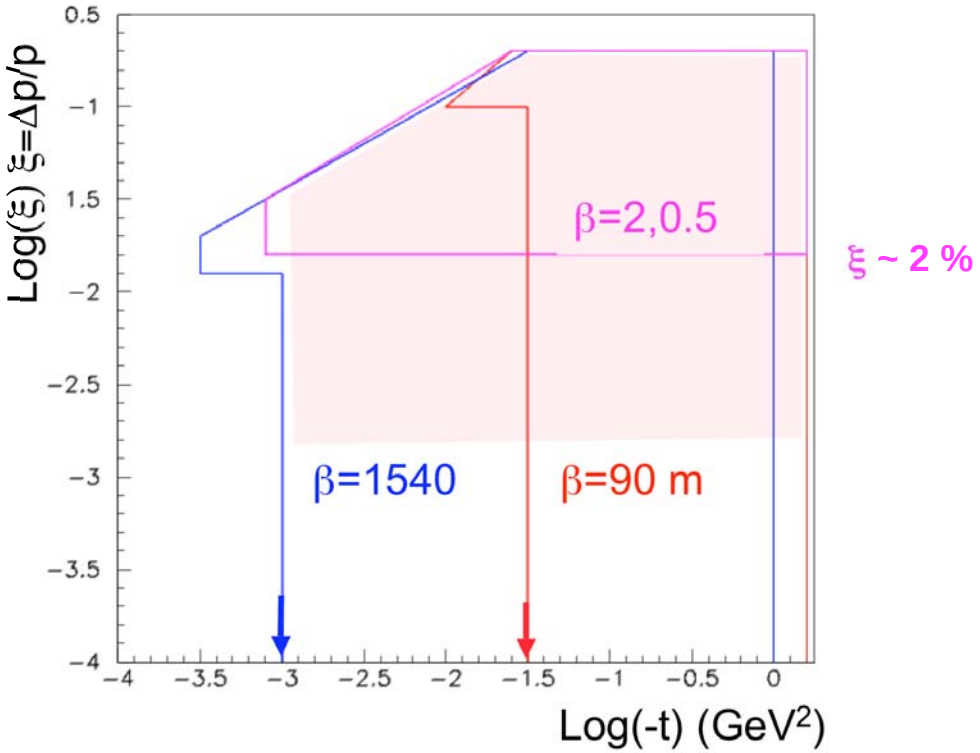
Detect the proton via:

its momentum loss (low β)

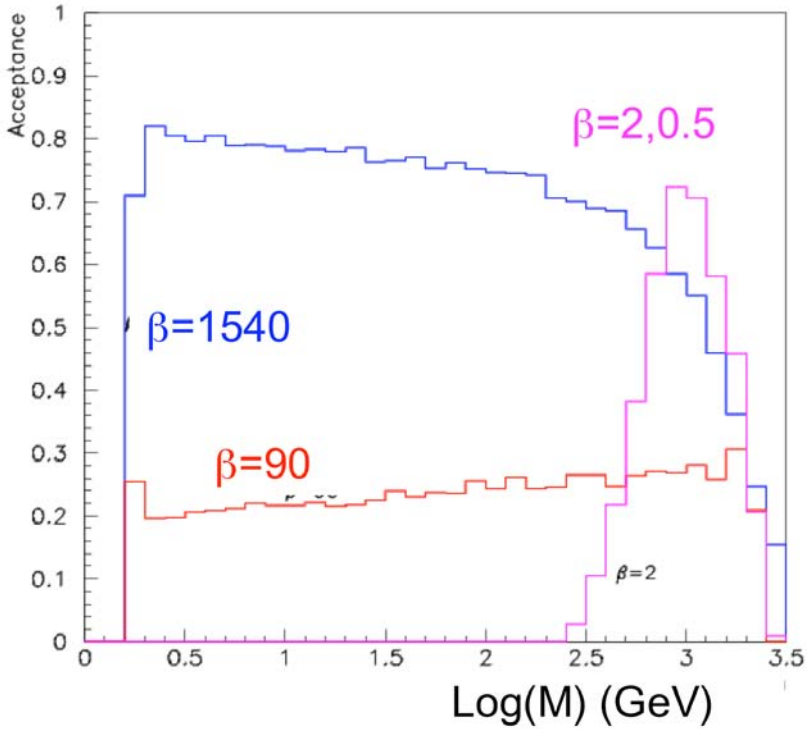
its transverse momentum (high β)

Measurement of Forward Protons: the Acceptances

DPE



ξ ~ 2 %



Variables in diffraction: ξ, t and related mass M

Measure individual cross-sections and the correlation between the above variables

Study of the corresponding rapidity gap and its suppression

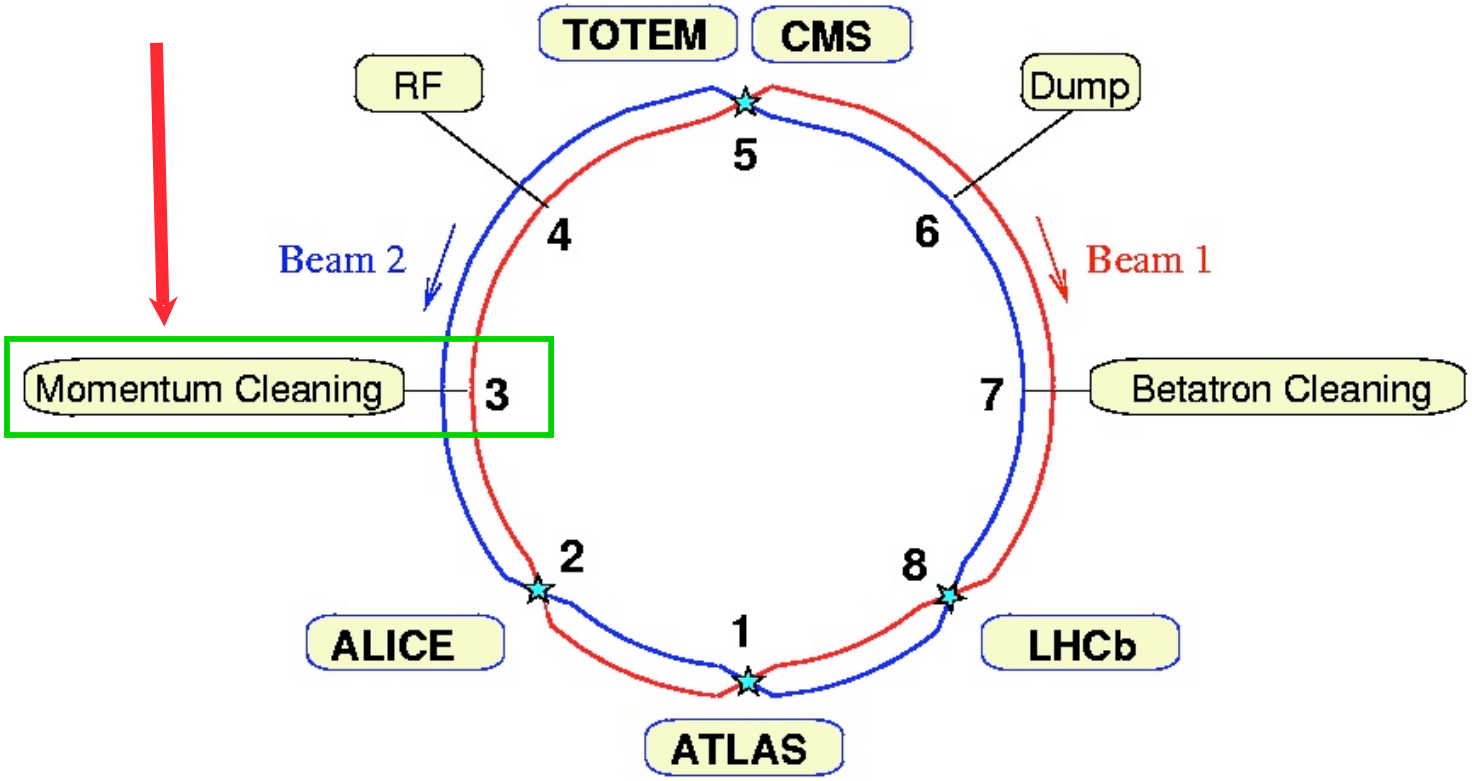
Outlook: Proton Detection at Lower ξ-Values

Good acceptance and momentum resolution for diffractive protons needs:

large dispersion D (few m) (x = ξ D)

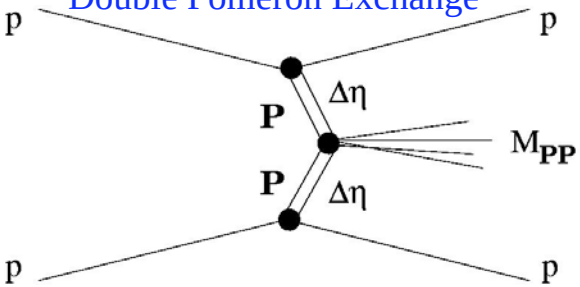
small beam width (< 1 mm)

Where in the LHC is it easy and are these requirements best fulfilled?



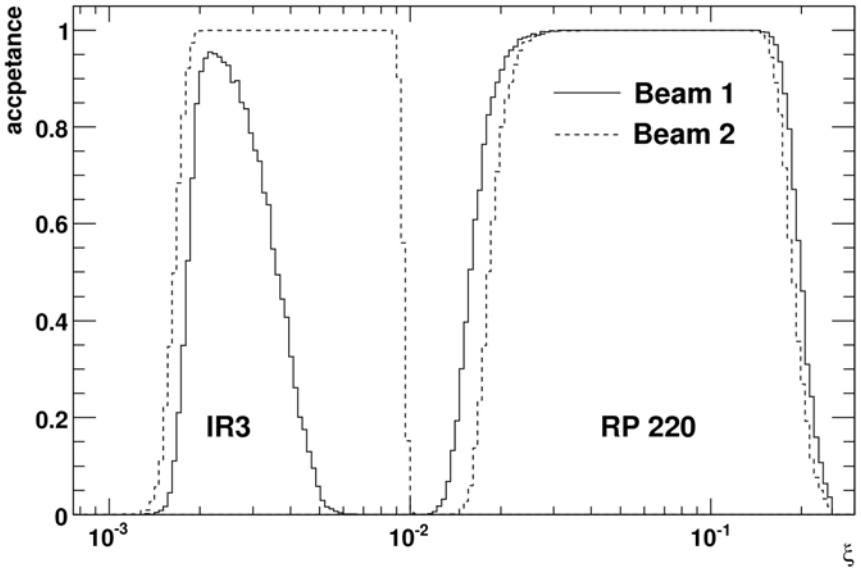
Proton Acceptance of a "Combined IP3 + RP220 TOTEM" Experiment

Double Pomeron Exchange

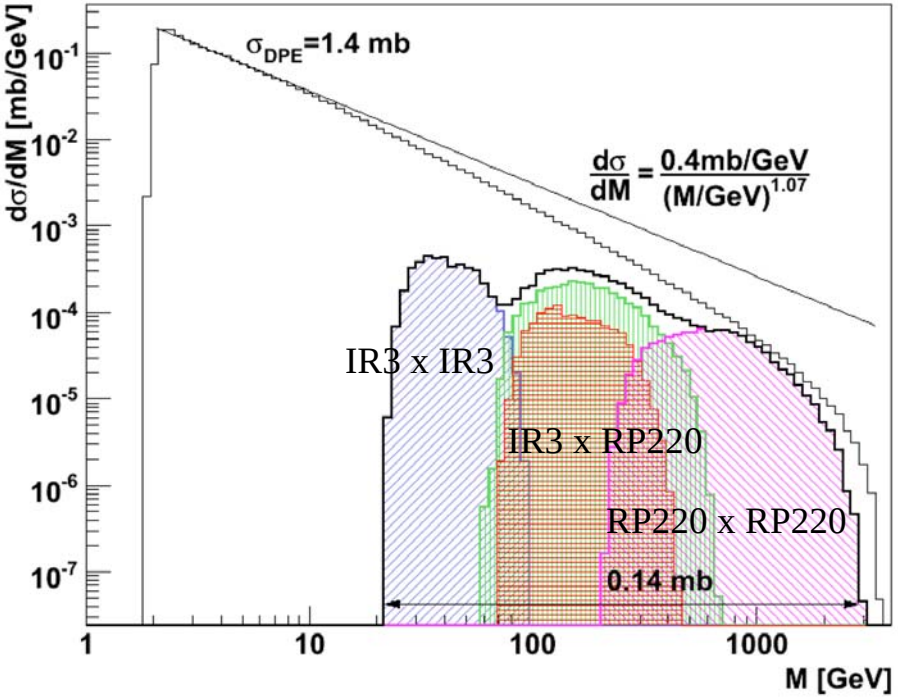


$$M_{PP}^2 = \xi_1 \, \xi_2 \, s$$

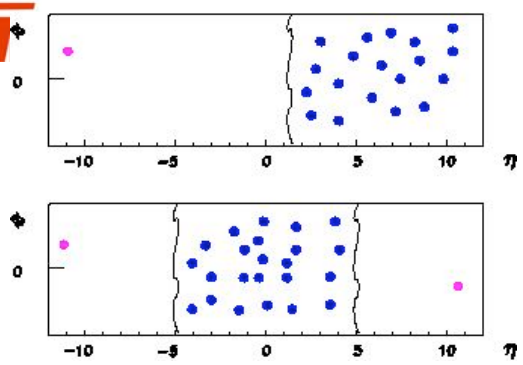
ξ-Acceptance

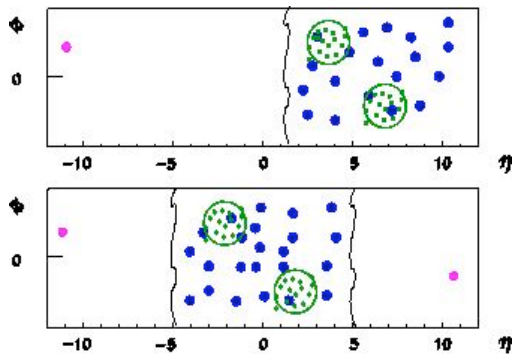


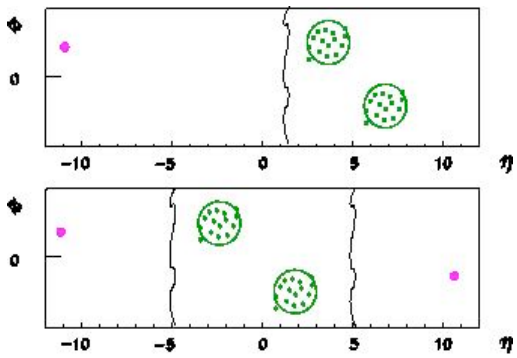
DPE Mass Spectrum with Detector Acceptance



Running scenarios also with CMS







pp->pX pp->pXp	pp->pjjX pp->pjjXp	pp->pjj (bosons, heavy pp->pjjp quarks,Higgs...)
soft diffraction	(semi)-hard diffraction	hard diffraction

Cross section ⟵ ⟶ Luminosity

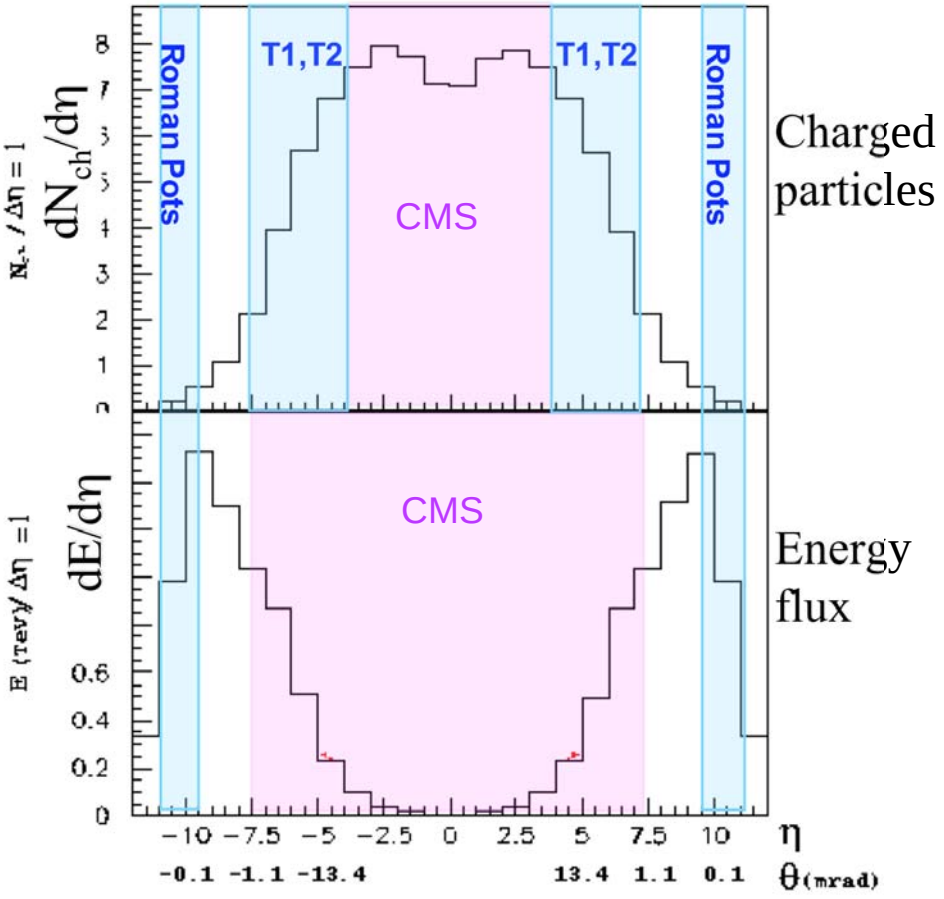
β (m)	1540	90	2	0.5	
L (cm^{-2} s^{-1})	10^{29}	10^{30}	10^{32}		10^{34}
	TOTEM runs			Standard runs	

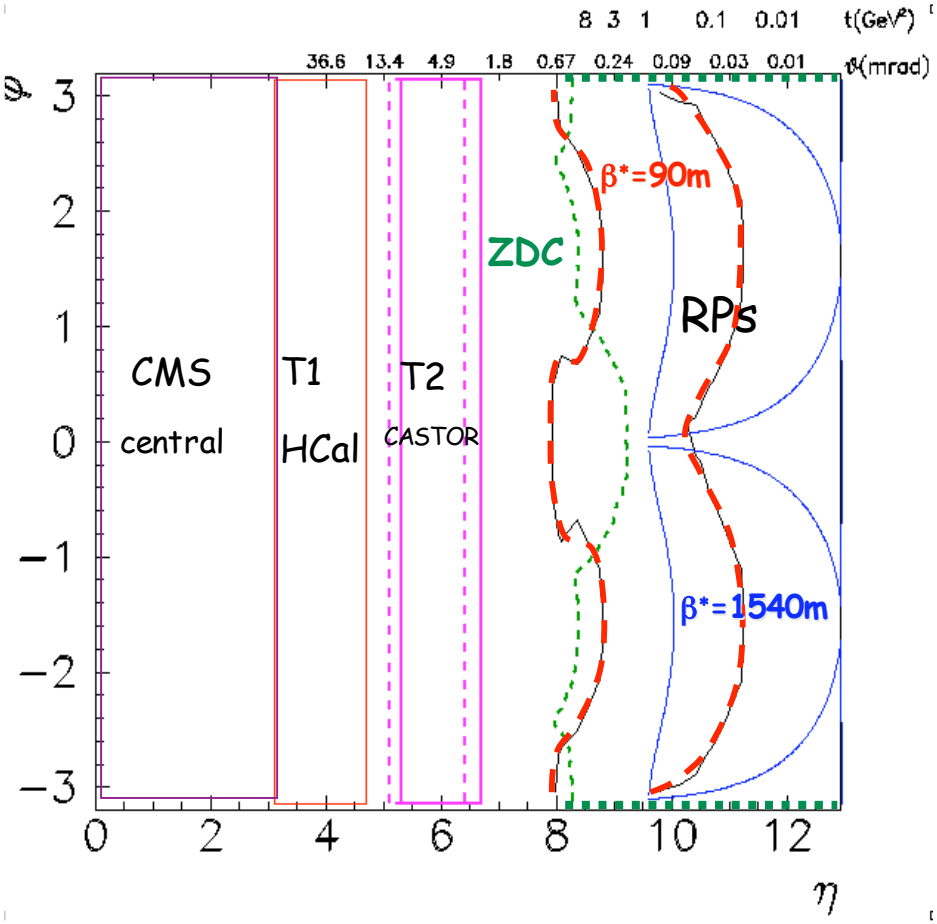
Accessible physics depends on luminosity & β*

CMS + TOTEM: Acceptance

largest acceptance detector ever built at a hadron collider

90% (65%) of all diffractive protons are detected for $\beta^* = 1540$ (90) m





$\eta = -\ln \operatorname{tg} \theta/2$

pp Interactions

Non-diffractive

Colour exchange

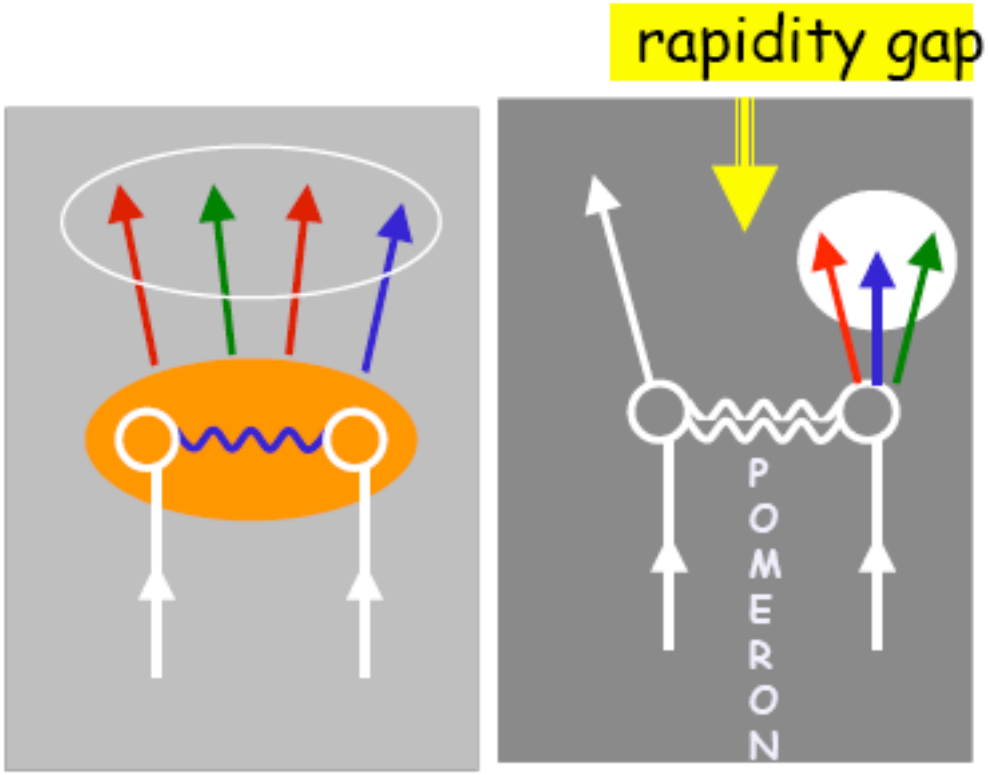
dN / d Δη = exp (-Δη)

Diffractive

Colourless exchange with vacuum quantum numbers

dN / d Δη = const

Incident hadrons acquire colour and break apart



Incident hadrons retain their quantum numbers remaining colourless

GOAL: understand the QCD nature of the diffractive exchange

TOTEM

- will be ready for the runs in 2009
- will run under all beam conditions with a complete detector in 2009
- will need special high β^* runs (hopefully in 2009) for:
  - total cross-section
  - diffraction
- will pursue a common physics program with CMS in a later stage

Diffractive scattering is a unique laboratory of confinement & QCD:
A hard scale + protons which remain intact in the scattering process


The TOTEM Collaboration
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MTA KFKI RMKI, Budapest, Hungary
Academy of Sciences, Praha, Czech Republic
CERN, Geneva, Switzerland
Università di Siena and Sezione INFN-Pisa, Italy
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University of Helsinki and HIP Helsinki, Finland